US009079222B2

(12) **United States Patent**
Burnett et al.

(10) **Patent No.: US 9,079,222 B2**
(45) **Date of Patent: Jul. 14, 2015**

(54) **SHALE SHAKER**

(75) Inventors: **George Alexander Burnett**, Aberdeen (GB); **Thomas Robert Larson**, Montgomery, TX (US)

(73) Assignee: **National Oilwell Varco, L.P.**, Houston, TX (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 1211 days.

(21) Appl. No.: **12/771,201**

(22) Filed: **Apr. 30, 2010**

(65) **Prior Publication Data**

US 2010/0270216 A1 Oct. 28, 2010

Related U.S. Application Data

(63) Continuation-in-part of application No. 12/490,492, filed on Jun. 24, 2009, now Pat. No. 8,556,083, which is a continuation-in-part of application No. 12/287,709, filed on Oct. 10, 2008, now Pat. No. 8,113,356.

(51) **Int. Cl.**

B07B 1/28	(2006.01)
B07B 1/46	(2006.01)
B01D 33/03	(2006.01)
B07B 13/16	(2006.01)

(52) **U.S. Cl.**

CPC ***B07B 1/46*** (2013.01); ***B01D 33/0376*** (2013.01); ***B07B 13/16*** (2013.01); *B07B 2201/04* (2013.01); *B07B 2230/01* (2013.01)

(58) **Field of Classification Search**

CPC B07B 1/46; B07B 1/00; B07B 13/16; B07B 2201/04; B07B 2230/01; B01D 33/41

USPC 209/258, 311, 314, 315, 360

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

599,468	A	2/1898	Cross	
865,185	A	9/1907	Kerrigan	
1,344,747	A	1/1920	Wright	
1,462,804	A	7/1923	Evans	
1,822,298	A	9/1931	Kerrigan	
1,830,792	A	11/1931	Herrmann	209/401

(Continued)

FOREIGN PATENT DOCUMENTS

DE	4127929 A1	2/1993
FR	2 611 559	9/1988

(Continued)

OTHER PUBLICATIONS

U.S. Appl. No. 12/785,735 Office Action dated Dec. 9, 2011.

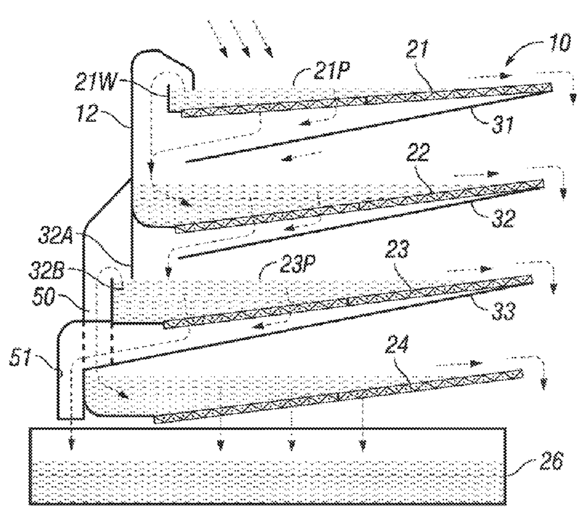
(Continued)

Primary Examiner — Joseph C Rodriguez
Assistant Examiner — Kalyanavenkateshware Kumar
(74) *Attorney, Agent, or Firm* — Amerson Law Firm, PLLC

(57) **ABSTRACT**

A shale shaker for separating solids from solids laden drilling fluid is disclosed as having a basket with a scalping screen deck, at least one first screen deck and at least one second screen deck. The basket further may have a flow tray arranged between said scalping screen deck and at least one first screen deck, and a plurality of first ducts and a plurality of second ducts, the plurality of first ducts for directing solids laden drilling fluid to the at least one first screen deck. The second plurality of second ducts are for directing solids laden drilling fluid to said second screen deck.

43 Claims, 37 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

1,885,154	A	11/1932	Strezynski et al.	
1,886,174	A	11/1932	Hazeltine	209/269
1,950,861	A	3/1934	O'Toole, Sr.	
2,082,513	A	6/1937	Roberts	210/76
2,089,548	A	8/1937	Frantz et al.	210/389
2,112,784	A	3/1938	McNiff	99/105
2,341,169	A	2/1944	Wilson et al.	73/51
2,418,529	A	4/1947	Stern	51/309
2,578,456	A	12/1951	Smith	233/7
2,653,521	A	9/1953	Einarsson	209/70
2,711,854	A	6/1955	Kjellgren	494/53
2,716,493	A	8/1955	Hutchison	209/269 X
2,750,043	A	6/1956	Thompson	210/149
2,895,669	A	7/1959	Bobo	494/10
2,919,898	A	1/1960	Marwil et al.	255/1.8
2,928,546	A	3/1960	Church	210/319
2,938,393	A	5/1960	Dunn et al.	74/61
2,942,731	A	6/1960	Soldini	209/293
2,955,753	A	10/1960	O'Conor et al.	494/5
2,961,154	A	11/1960	Bergey	494/1
3,012,674	A	12/1961	Hoppe	209/401
3,053,379	A	9/1962	Roder et al.	198/220
3,064,806	A	11/1962	Tapani	209/17
3,070,291	A	12/1962	Bergey	494/1
3,219,107	A	11/1965	Brown et al.	166/8
3,226,989	A	1/1966	Robins	74/87
3,268,159	A	8/1966	Kern	233/7
3,302,720	A	2/1967	Brandon	166/42
3,498,393	A	3/1970	West et al.	175/48
3,605,919	A	9/1971	Bromell et al.	175/27
3,629,859	A	12/1971	Copland et al.	340/172.5
3,640,344	A	2/1972	Brandon	166/307
3,659,465	A	5/1972	Oshima et al.	74/61
3,726,136	A	4/1973	McKean et al.	73/155
3,795,361	A	3/1974	Lee	233/7
3,796,299	A	3/1974	Musschoot	198/220
3,855,380	A	12/1974	Gordon et al.	264/97
3,874,733	A	4/1975	Poundstone et al.	299/17
3,885,734	A	5/1975	Lee	233/3
3,900,393	A	8/1975	Wilson	209/399
3,934,792	A	1/1976	High et al.	233/7
3,955,411	A	5/1976	Lawson, Jr.	73/155
3,968,033	A	7/1976	Illemann et al.	209/403
3,993,146	A	11/1976	Poundstone et al.	175/206
4,000,074	A	12/1976	Evans	210/369
4,019,987	A	4/1977	Krasnow	
4,022,596	A	5/1977	Pedersen	
4,033,865	A	7/1977	Derrick, Jr.	209/275
4,038,152	A	7/1977	Atkins	201/2.5
4,082,657	A	4/1978	Gage	209/311
4,085,888	A	4/1978	Jager	233/7
4,115,507	A	9/1978	Pico et al.	264/267
4,116,288	A	9/1978	Love	175/66
4,192,743	A	3/1980	Bastgen et al.	210/712
4,208,906	A	6/1980	Roberts, Jr.	73/155
4,212,731	A	7/1980	Wallin et al.	209/366.5
4,222,988	A	9/1980	Barthel	422/309
4,224,821	A	9/1980	Taylor et al.	73/32 R
4,228,949	A	10/1980	Jackson	233/7
4,233,181	A	11/1980	Goller et al.	252/425.3
4,240,578	A	12/1980	Jackson	233/7
4,297,225	A	10/1981	Hartley	210/779
4,298,160	A	11/1981	Jackson	233/7
4,298,162	A	11/1981	Hohne	233/7
4,298,572	A	11/1981	Moffet et al.	422/68
4,306,974	A	12/1981	Harry	210/388
4,319,482	A	3/1982	Bunner	73/153
4,319,991	A	3/1982	Crone, Jr. et al.	209/255
4,322,288	A *	3/1982	Schmidt	209/356
4,339,072	A	7/1982	Hiller	233/7
4,350,591	A	9/1982	Lee	210/384
4,369,915	A	1/1983	Oberg et al.	494/8
4,378,906	A	4/1983	Epper et al.	494/54
4,411,074	A	10/1983	Daly	34/32
4,432,064	A	2/1984	Barker et al.	364/550
4,446,022	A	5/1984	Harry	210/388
4,459,207	A	7/1984	Young	209/269
4,482,459	A	11/1984	Shiver	210/639
4,495,065	A	1/1985	DeReamer et al.	209/243
4,526,687	A	7/1985	Nugent	210/202
4,536,286	A	8/1985	Nugent	210/202
4,546,783	A	10/1985	Lott	134/109
4,549,431	A	10/1985	Soeiinah	73/152.49
4,553,429	A	11/1985	Evans et al.	73/152.21
4,573,115	A	2/1986	Halgrimson	364/138
4,575,336	A	3/1986	Mudd et al.	432/72
4,606,415	A	8/1986	Gray, Jr. et al.	175/24
4,624,417	A	11/1986	Gangi	241/17
4,634,535	A	1/1987	Lott	210/780
4,635,735	A	1/1987	Crownover	175/48
4,639,258	A	1/1987	Schellstede et al.	95/260
4,650,687	A	3/1987	Willard et al.	426/438
4,668,213	A	5/1987	Kramer	494/8
4,685,329	A	8/1987	Burgess	73/151
4,696,353	A	9/1987	Elmquist et al.	175/206
4,696,751	A	9/1987	Eifling	210/780
4,729,548	A	3/1988	Sullins	266/44
4,743,226	A	5/1988	Day et al.	494/53
4,751,887	A	6/1988	Terry et al.	110/246
4,770,711	A	9/1988	Deal, III et al.	134/18
4,783,057	A	11/1988	Sullins	266/44
4,791,002	A	12/1988	Baker et al.	426/641
4,793,421	A	12/1988	Jasinski	175/27
4,795,552	A	1/1989	Yun et al.	209/319
4,799,987	A	1/1989	Sullins	156/425
4,805,659	A	2/1989	Gunnewig et al.	137/118
4,807,469	A	2/1989	Hall	73/155
4,809,791	A	3/1989	Hayatdavoudi	175/40
4,832,853	A	5/1989	Shiraki et al.	210/781
4,844,106	A	7/1989	Hunter et al.	134/73
4,846,352	A	7/1989	Bailey	209/399
4,857,176	A	8/1989	Derrick et al.	209/392
4,882,054	A	11/1989	Derrick et al.	210/389
4,889,733	A	12/1989	Willard et al.	426/438
4,889,737	A	12/1989	Willard et al.	426/550
4,892,767	A	1/1990	Freissle	
4,895,665	A	1/1990	Colelli et al.	210/710
4,895,731	A	1/1990	Baker et al.	426/641
4,896,835	A	1/1990	Fahrenholz	241/74
4,911,834	A	3/1990	Murphy	210/167
4,915,452	A	4/1990	Dibble	299/17
4,940,535	A	7/1990	Fisher et al.	209/250
4,942,929	A	7/1990	Malachosky et al.	175/66
4,961,722	A	10/1990	Taylor et al.	494/36
5,010,966	A	4/1991	Stokley et al.	175/66
5,053,082	A	10/1991	Flanigan et al.	134/25.1
5,066,350	A	11/1991	Sullins	156/187
5,080,721	A	1/1992	Flanigan et al.	134/26
5,107,874	A	4/1992	Flanigan et al.	134/60
5,109,933	A	5/1992	Jackson	175/66
5,129,469	A	7/1992	Jackson	175/66
5,131,271	A	7/1992	Haynes et al.	73/290
5,145,256	A	9/1992	Wiemers et al.	366/336
5,147,277	A	9/1992	Shapiro	494/53
5,156,749	A	10/1992	Williams	210/770
5,156,751	A	10/1992	Miller	210/787
5,181,578	A	1/1993	Lawler	175/424
5,190,645	A	3/1993	Burgess	210/144
5,200,372	A	4/1993	Kuroyama et al.	501/96
5,203,762	A	4/1993	Cooperstein	494/7
5,211,291	A	5/1993	Kelley et al.	
5,221,008	A	6/1993	Derrick, Jr. et al.	209/269
5,226,546	A	7/1993	Janssens et al.	209/319
5,227,057	A	7/1993	Lundquist	210/174
5,229,018	A	7/1993	Forrest	252/8.551
5,232,099	A	8/1993	Maynard	209/311
5,253,718	A	10/1993	Lawler	175/20
5,265,730	A	11/1993	Norris et al.	209/326
5,273,112	A	12/1993	Schultz	166/374
5,278,549	A	1/1994	Crawford	340/853.2
5,314,058	A	5/1994	Graham	198/753
5,319,972	A	6/1994	Oblak et al.	73/290
5,329,465	A	7/1994	Arcella et al.	364/551.01
5,332,101	A	7/1994	Bakula	209/403

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,337,966	A	8/1994	Francis et al.	241/46.06
5,378,364	A	1/1995	Welling	210/512.1
5,385,669	A	1/1995	Leone, Sr.	210/488
5,392,925	A	2/1995	Seyffert	209/405
5,400,376	A	3/1995	Trudeau	377/21
5,403,260	A	4/1995	Hensley	494/53
5,454,957	A	10/1995	Roff	210/768
5,465,798	A	11/1995	Edlund et al.	175/24
5,474,142	A	12/1995	Bowden	175/27
5,488,104	A	1/1996	Schulz	536/86
5,489,204	A	2/1996	Conwell et al.	432/153
5,494,584	A	2/1996	McLachlan et al.	210/739
5,516,348	A	5/1996	Conwell et al.	51/309
5,534,207	A	7/1996	Burrus	264/150
5,547,479	A	8/1996	Conwell et al.	51/309
5,566,889	A	10/1996	Preiss	241/19
5,567,150	A	10/1996	Conwell et al.	432/14
5,570,749	A	11/1996	Reed	175/66
5,597,042	A	1/1997	Tubel et al.	166/250.01
5,632,714	A	5/1997	Leung et al.	494/53
5,638,960	A	6/1997	Beuermann et al.	209/397
5,641,070	A	6/1997	Seyffert	209/314
5,643,169	A	7/1997	Leung et al.	494/53
5,653,674	A	8/1997	Leung	494/53
5,662,165	A	9/1997	Tubel et al.	166/250.01
5,669,941	A	9/1997	Peterson	51/295
5,681,256	A	10/1997	Nagafuji	494/9
D386,874	S	11/1997	Glaun	D34/29
D387,534	S	12/1997	Glaun	D34/29
D388,583	S	12/1997	Glaun	D34/29
5,695,442	A	12/1997	Leung et al.	494/37
5,699,918	A	12/1997	Dunn	209/397
D388,924	S	1/1998	Glaun	D34/29
5,706,896	A	1/1998	Tubel et al.	166/313
5,730,219	A	3/1998	Tubel et al.	166/250.01
5,732,776	A	3/1998	Tubel et al.	166/250.15
5,732,828	A	3/1998	Littlefield, Jr.	209/365.1
5,771,601	A	6/1998	Veal et al.	34/314
5,772,573	A	6/1998	Hao	494/15
5,791,494	A	8/1998	Meyer	209/368
5,793,705	A	8/1998	Gazis et al.	367/98
5,811,003	A	9/1998	Young et al.	210/388
5,814,230	A	9/1998	Willis et al.	210/710
5,816,413	A	10/1998	Boccabella et al.	209/399
5,819,952	A	10/1998	Cook et al.	209/400
5,839,521	A	11/1998	Dietzen	100/37
5,857,955	A	1/1999	Phillips et al.	494/7
5,861,362	A	1/1999	Mayeux et al.	507/104
5,868,125	A	2/1999	Maoujoud	125/15
5,896,998	A	4/1999	Bjorklund et al.	209/326
5,899,844	A	5/1999	Eberle, Sr.	494/37
5,913,767	A	6/1999	Feldkamp et al.	494/4
5,919,123	A	7/1999	Phillips	494/7
5,942,130	A	8/1999	Leung	210/784
5,944,197	A	8/1999	Baltzer et al.	209/400
5,948,256	A	9/1999	Leung	210/374
5,948,271	A	9/1999	Wardwell et al.	210/739
5,952,569	A	9/1999	Jervis et al.	73/152.01
5,955,666	A	9/1999	Mullins	73/152.18
5,958,235	A	9/1999	Leung	210/374
5,971,159	A	10/1999	Leone et al.	209/399
5,971,307	A	10/1999	Davenport	241/259.1
5,975,204	A	11/1999	Tubel et al.	166/250.15
5,992,519	A	11/1999	Ramakrishnan et al.	166/250.15
6,012,016	A	1/2000	Bilden et al.	702/12
6,013,158	A	1/2000	Wootten	202/99
6,021,377	A	2/2000	Dubinsky et al.	702/9
6,024,228	A	2/2000	Williams	209/272
6,045,070	A	4/2000	Davenport	241/60
6,062,070	A	5/2000	Maltby et al.	73/61.49
6,063,292	A	5/2000	Leung	210/739
6,089,380	A	7/2000	Hazrati et al.	210/411
6,102,310	A	8/2000	Davenport	241/21
6,105,689	A	8/2000	McGuire et al.	175/48
6,109,452	A	8/2000	Leung et al.	210/369
6,110,096	A	8/2000	Leung et al.	494/53
6,123,656	A	9/2000	Michelsen	494/54
6,138,834	A	10/2000	Southall	209/17
6,143,183	A	11/2000	Wardwell et al.	210/739
6,145,669	A	11/2000	Leung	210/374
6,155,428	A	12/2000	Bailey et al.	209/315
6,161,700	A	12/2000	Bakula	209/401
6,165,323	A	12/2000	Shearer	162/251
6,170,580	B1	1/2001	Reddoch	175/66
6,173,609	B1	1/2001	Modlin et al.	73/293
6,176,323	B1	1/2001	Weirich et al.	175/40
6,179,128	B1	1/2001	Seyffert	209/405
6,192,742	B1	2/2001	Miwa et al.	73/40
6,192,980	B1	2/2001	Tubel et al.	166/65.1
6,217,830	B1	4/2001	Roberts et al.	422/140
6,223,906	B1	5/2001	Williams	210/400
6,233,524	B1	5/2001	Harrell et al.	702/9
6,234,250	B1	5/2001	Green et al.	166/250.03
6,237,404	B1	5/2001	Crary et al.	73/152.03
6,267,250	B1	7/2001	Leung et al.	210/369
6,279,471	B1	8/2001	Reddoch	100/37
D448,488	S	9/2001	Chaffiotte et al.	D24/219
6,283,302	B1	9/2001	Schulte et al.	209/399
6,290,636	B1	9/2001	Hiller, Jr. et al.	494/53
6,308,787	B1	10/2001	Alft	175/48
6,315,894	B1	11/2001	Wiemers et al.	210/96.1
6,333,700	B1	12/2001	Thomeer et al.	340/854.8
6,346,813	B1	2/2002	Kleinberg	324/303
6,349,834	B1	2/2002	Carr et al.	209/366.5
6,352,159	B1	3/2002	Loshe	209/268
6,356,205	B1	3/2002	Salvo et al.	340/853.3
6,367,633	B1	4/2002	Douglas	209/311
6,368,264	B1	4/2002	Phillips et al.	494/5
6,371,301	B1	4/2002	Schulte et al.	209/405
6,378,628	B1	4/2002	McGuire et al.	175/48
6,393,363	B1	5/2002	Wilt et al.	702/6
6,399,851	B1	6/2002	Siddle	203/87
6,408,953	B1	6/2002	Goldman et al.	175/39
6,412,644	B1	7/2002	Crabbe et al.	209/309
6,429,653	B1	8/2002	Kruspe et al.	324/303
6,438,495	B1	8/2002	Chau et al.	702/9
6,439,391	B1	8/2002	Seyffert	209/238
6,461,286	B1	10/2002	Beatley	494/8
6,474,143	B1	11/2002	Herod	73/54.01
6,484,088	B1	11/2002	Reimer	701/123
6,484,885	B1	11/2002	Lilie et al.	
6,485,640	B2	11/2002	Fout et al.	210/188
6,505,682	B2	1/2003	Brockman	166/250.15
6,506,310	B2	1/2003	Kulbeth	210/780
6,510,947	B1	1/2003	Schulte et al.	210/388
6,513,664	B1	2/2003	Logan et al.	209/367
6,517,733	B1	2/2003	Carlson	210/785
6,519,568	B1	2/2003	Harvey et al.	705/1
6,530,482	B1	3/2003	Wiseman	209/253
6,536,540	B2	3/2003	deBoer	175/70
6,553,316	B2	4/2003	Bary et al.	702/16
6,553,336	B1	4/2003	Johnson et al.	702/188
6,575,304	B2	6/2003	Cudahy	209/365.3
6,581,455	B1	6/2003	Berger et al.	73/152.55
6,600,278	B1	7/2003	Bretzius	318/34
6,601,709	B2	8/2003	Schulte et al.	209/397
6,605,029	B1	8/2003	Koch et al.	494/53
6,662,952	B2	12/2003	Adams et al.	209/319
6,669,027	B1	12/2003	Mooney et al.	209/405
6,679,385	B2	1/2004	Suter et al.	209/367
6,691,025	B2	2/2004	Reimer	701/123
6,693,553	B1	2/2004	Ciglenec et al.	340/853.1
6,715,612	B1	4/2004	Krystof	209/331
6,722,504	B2	4/2004	Schulte et al.	209/359
6,746,602	B2	6/2004	Fout et al.	210/188
6,763,605	B2	7/2004	Reddoch	34/58
6,766,254	B1	7/2004	Bradford et al.	702/9
6,769,550	B2	8/2004	Adams et al.	209/399
6,780,147	B2	8/2004	Koch et al.	494/53
6,783,088	B1	8/2004	Gillis et al.	241/19
6,783,685	B2	8/2004	Huang	210/690
6,790,169	B2	9/2004	Koch et al.	494/53
6,793,814	B2	9/2004	Fout et al.	210/188
6,808,626	B2	10/2004	Kulbeth	210/241

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,827,223	B2	12/2004	Colgrove et al.	209/365.3
6,838,008	B2	1/2005	Fout et al.	210/780
6,860,845	B1	3/2005	Miller et al.	494/1
6,863,183	B2	3/2005	Schulte et al.	209/405
6,863,809	B2	3/2005	Smith et al.	210/202
6,868,920	B2	3/2005	Hoteit et al.	175/25
6,868,972	B2	3/2005	Seyffert et al.	209/254
6,873,267	B1	3/2005	Tubel et al.	340/853.3
6,892,812	B2	5/2005	Niedermayr et al.	166/250.15
6,896,055	B2	5/2005	Koithan	166/250.15
6,899,178	B2	5/2005	Tubel	166/313
6,905,452	B1	6/2005	Kirsch	494/8
6,907,375	B2	6/2005	Guggari et al.	702/113
6,926,101	B2	8/2005	deBoer	175/70
6,932,169	B2	8/2005	Wylie et al.	175/66
6,932,757	B2	8/2005	Beattey	494/55
6,971,982	B1	12/2005	Kirsch	494/8
6,981,940	B2	1/2006	Rafferty	494/7
7,001,324	B2	2/2006	Hensley et al.	494/53
7,018,326	B2	3/2006	Koch et al.	494/53
7,041,044	B2	5/2006	Gilbert	494/53
D524,825	S	7/2006	Koch et al.	D15/21
7,093,678	B2	8/2006	Risher et al.	175/66
7,144,516	B2	12/2006	Smith	210/803
7,175,027	B2	2/2007	Strong et al.	209/405
7,195,084	B2	3/2007	Burnett et al.	175/66
7,198,156	B2	4/2007	Schulte et al.	209/309
7,216,767	B2	5/2007	Schulte et al.	209/309
7,228,971	B2	6/2007	Mooney et al.	209/396
7,264,125	B2	9/2007	Lipa	209/397
7,284,665	B2	10/2007	Fuchs	209/270
7,303,079	B2	12/2007	Reid-Robertson et al.	209/405
7,306,057	B2	12/2007	Strong et al.	175/66
7,316,321	B2	1/2008	Robertson et al.	209/400
7,337,860	B2	3/2008	McIntyre	175/66
7,373,996	B1	5/2008	Martin et al.	175/206
7,387,602	B1	6/2008	Kirsch	494/8
7,514,011	B2	4/2009	Kulbeth	210/780
7,540,837	B2	6/2009	Scott et al.	494/7
7,540,838	B2	6/2009	Scott et al.	494/7
7,581,569	B2	9/2009	Beck	139/425 R
7,703,612	B2 *	4/2010	Browne et al.	209/311
7,770,665	B2	8/2010	Eia et al.	175/66
2001/0032815	A1	10/2001	Adams et al.	210/388
2002/0000399	A1	1/2002	Winkler et al.	209/399
2002/0018399	A1	2/2002	Schultz et al.	361/81
2002/0033278	A1	3/2002	Reddoch	175/57
2002/0033358	A1	3/2002	Bakula	209/331
2002/0035551	A1	3/2002	Sherwin et al.	705/412
2002/0065698	A1	5/2002	Schick et al.	705/8
2002/0112888	A1	8/2002	Leuchtenberg	175/48
2002/0134709	A1	9/2002	Riddle	209/238
2003/0015351	A1	1/2003	Goldman et al.	175/39
2003/0038734	A1	2/2003	Hirsch et al.	340/853.1
2003/0109951	A1	6/2003	Hsiung et al.	700/108
2003/0220742	A1	11/2003	Niedermayr et al.	702/9
2004/0040746	A1	3/2004	Niedermayr et al.	175/38
2004/0051650	A1	3/2004	Gonsoulin et al.	340/853.1
2004/0156920	A1	8/2004	Kane	424/725
2004/0245155	A1	12/2004	Strong et al.	209/405
2005/0103689	A1	5/2005	Schulte, Jr. et al.	209/405
2005/0236305	A1	10/2005	Schulte, Jr. et al.	209/403
2005/0255186	A1	11/2005	Hiraga	425/542
2006/0019812	A1	1/2006	Stalwick	494/42
2006/0034988	A1	2/2006	Bresnahan et al.	426/502
2006/0081508	A1	4/2006	Astleford et al.	209/309
2006/0102390	A1	5/2006	Burnett et al.	175/66
2006/0105896	A1	5/2006	Smith et al.	494/7
2006/0144779	A1	7/2006	Bailey	210/330
2007/0108105	A1	5/2007	Burnett	
2007/0108106	A1	5/2007	Burnett	209/325
2007/0131592	A1	6/2007	Browne et al.	209/399
2008/0078697	A1	4/2008	Carr	209/49
2008/0078702	A1	4/2008	Carr et al.	209/326
2008/0078704	A1	4/2008	Carr et al.	209/399
2008/0093269	A1	4/2008	Timmerman et al.	209/405
2008/0179090	A1	7/2008	Eia et al.	175/5
2008/0179096	A1	7/2008	Eia et al.	175/66
2008/0179097	A1	7/2008	Eia et al.	175/66
2009/0071878	A1	3/2009	Bosse	209/391
2009/0105059	A1	4/2009	Dorry et al.	494/37
2009/0178978	A1	7/2009	Beebe et al.	210/747
2009/0242466	A1	10/2009	Burnett et al.	209/555
2009/0286098	A1	11/2009	Yajima et al.	428/507
2009/0316084	A1	12/2009	Yajima et al.	349/96
2010/0084190	A1	4/2010	Eia et al.	175/5
2010/0119570	A1	5/2010	Potter et al.	424/422
2010/0237024	A1 *	9/2010	Carr et al.	210/780

FOREIGN PATENT DOCUMENTS

FR	2 636 669	3/1990
GB	1 526 663	9/1978
GB	2 030 482 A	4/1980
GB	1 578 948	11/1980
GB	2 176 424	12/1986
GB	2 327 442 A	1/1999
GB	2 408 006 B	4/2007
JP	55112761	8/1980
JP	59069268	4/1984
JP	63003090	1/1988
JP	63283860	11/1988
JP	63290705	11/1988
JP	02127030	5/1990
JP	02167834	6/1990
JP	03240925	10/1991
JP	03264263	11/1991
JP	04093045	3/1992
JP	04269170	9/1992
JP	05043884	2/1993
JP	05301158	11/1993
JP	06063499	3/1994
JP	07304028	11/1995
JP	08039428	2/1996
JP	08270355	10/1996
JP	09109032	4/1997
JP	10337598	12/1998
WO	WO96/08301	3/1996
WO	WO96/33792	10/1996
WO	WO98/10895	3/1998
WO	WO98/16328	4/1998
WO	WO2004/110589 A1	12/2004
WO	WO2005/107963 A2	11/2005
WO	WO 2008/042844 A1	4/2008
WO	WO2009/048783 A2	4/2009

OTHER PUBLICATIONS

U.S. Appl. No. 12/490,492 Office Action dated Oct. 7, 2011.
U.S. Appl. No. 12/321,358 Final Office Action dated Jan. 18, 2012.
U.S. Appl. No. 12/321,358 Office Action dated Aug. 29, 2011.
U.S. Appl. No. 12/287,716 Office Action dated Jun. 17, 2011.
U.S. Appl. No. 12/287,709 Office Action dated Mar. 29, 2011.
U.S. Appl. No. 12/231,293 Office Action dated Sep. 13, 2011.
U.S. Appl. No. 12/228,670 Office Action dated Jun. 20, 2011.
U.S. Appl. No. 12/227,462 Final Office Action dated May 26, 2011.
U.S. Appl. No. 12/008,980 Office Action dated Aug. 31, 2011.
U.S. Appl. No. 12/008,980 Office Action dated Apr. 5, 2011.
U.S. Appl. No. 12/001,479 Final Office Action dated Oct. 31, 2011.
U.S. Appl. No. 12/001,479 Office Action dated Jun. 8, 2011.
U.S. Appl. No. 11/897,975 Office Action dated Jun. 8, 2012.
U.S. Appl. No. 11/897,975 Final Office Action dated Aug. 12, 2011.
U.S. Appl. No. 11/897,975 Office Action dated Mar. 1, 2011.
U.S. Appl. No. 11/637,615 Final Office Action dated Nov. 16, 2011.
U.S. Appl. No. 11/637,615 Office Action dated Jul. 21, 2011.
International Search Report and Written Opinion from PCT/GB2010/051050 dated Jan. 30, 2012.
EP Application No. 07 733 775.6 EPC Communication dated Dec. 9, 2010.
Adams et al., "The Advanced Technology Linear Separator Model ATL-1000," Drexel Oilfield Services, STC 03, 18 pages (1991).

(56) **References Cited**

OTHER PUBLICATIONS

AMS 2000 Description, Thule Rigtech, Rig Technology, 18 pages (2000).
Automated Chemical Additive System, Thule Rigtech, Rig Technology Ltd., 4 pages (2000).
Brandt Automated Shaker Control, Varco, 1 page (2002).
Brandt®, A Varco Company, King Cobra Series, Installation, Operation, and Maintenance Manual, M12444 R5, 65 pages (2003).
Brandt®, A Varco Company, LCM-2D LP Installation and Operation Manual, 84 pages (1998).
Brandt et al., Mud Equipment Manual—Handbook 3: Shale Shakers, Gulf Pub. Co., 18 pages (1982).
The Derrick LP Sandwich Shaker, Derrick Equipment Company, 4 pages (1981).
Fluid Systems Inc., The Prodigy Series I™ Dynamic Control Shaker, 2 pages (Apr. 27, 2004).
Sweco® Oilfield Services, LM-3 Full-Flo™ Shale Shaker, 4 pages (1991).
U.S. Appl. No. 12/481,959 Final Office Action dated Oct. 27, 2010.
U.S. Appl. No. 12/481,959 Office Action dated Jun. 7, 2010.
U.S. Appl. No. 12/469,851 Final Office Action dated Nov. 9, 2010.
U.S. Appl. No. 12/469,851 Office Action dated Jun. 28, 2010.
U.S. Appl. No. 12/227,462 Office Action dated Nov. 15, 2010.
U.S. Appl. No. 11/897,976 Final Office Action dated Sep. 1, 2010.
U.S. Appl. No. 11/897,976 Office Action dated Apr. 1, 2010.
U.S. Appl. No. 11/897,975 Final Office Action dated Jul. 21, 2010.
U.S. Appl. No. 11/897,975 Office Action dated Feb. 19, 2010.
U.S. Appl. No. 11/637,615 Final Office Action dated Aug. 2, 2010.
U.S. Appl. No. 11/637,615 Office Action dated Mar. 2, 2010.
Polyamide 6/6—Nylon 6/6—PA 6/6 60% Glass Fibre Reinforced, Data Sheet [online], AZoM™, The A to Z of Materials and AZojomo, The "AZo Journal of Materials Online" [retrieved on Nov. 23, 2005] (2005) (Retrieved from the Internet: <URL: http://web.archive.org/web/20051123025735/http://www.azom.com/details.asp?ArticleID=493>.
International Search Report from PCT/GB2011/050975 dated Nov. 15, 2012.
Related U.S. Appl. No. 12/321,358 Office Action dated Feb. 5, 2015.

* cited by examiner

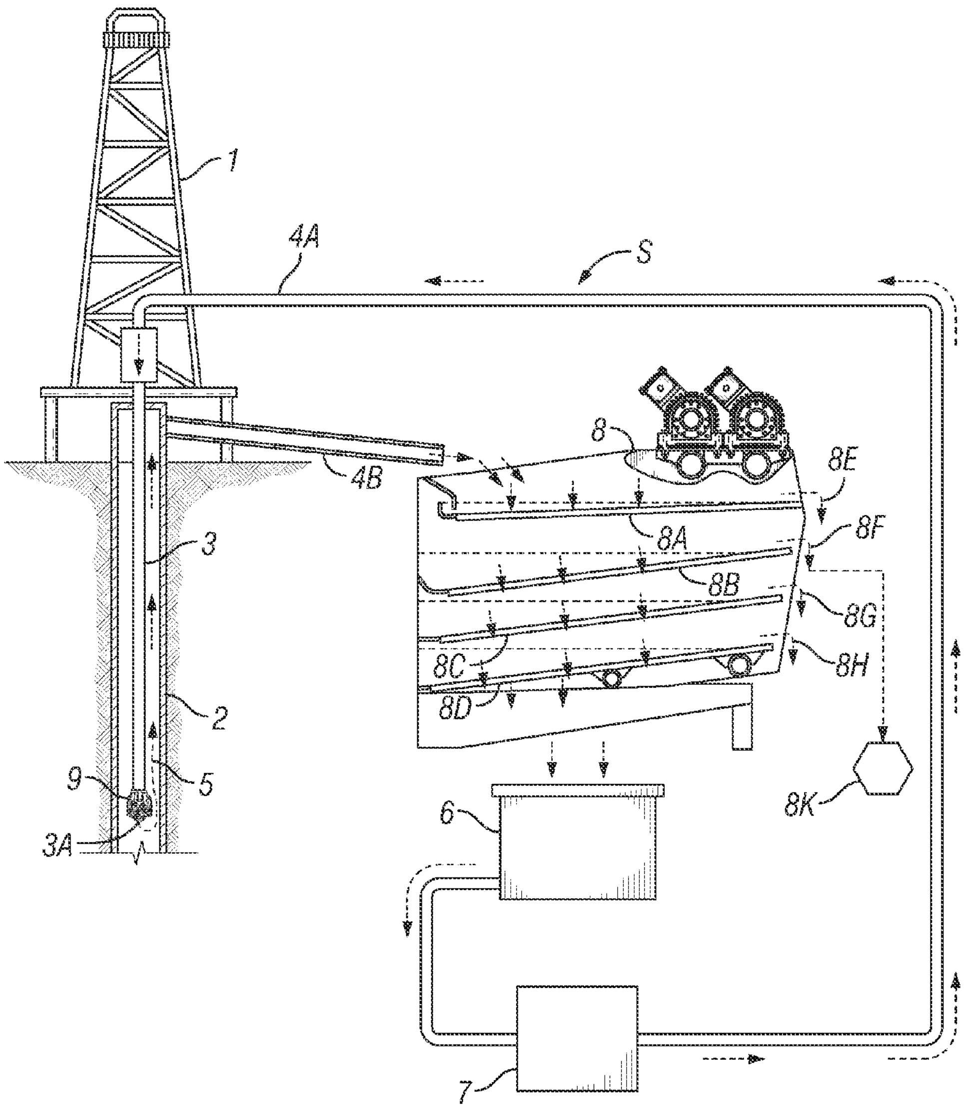


FIG. 1

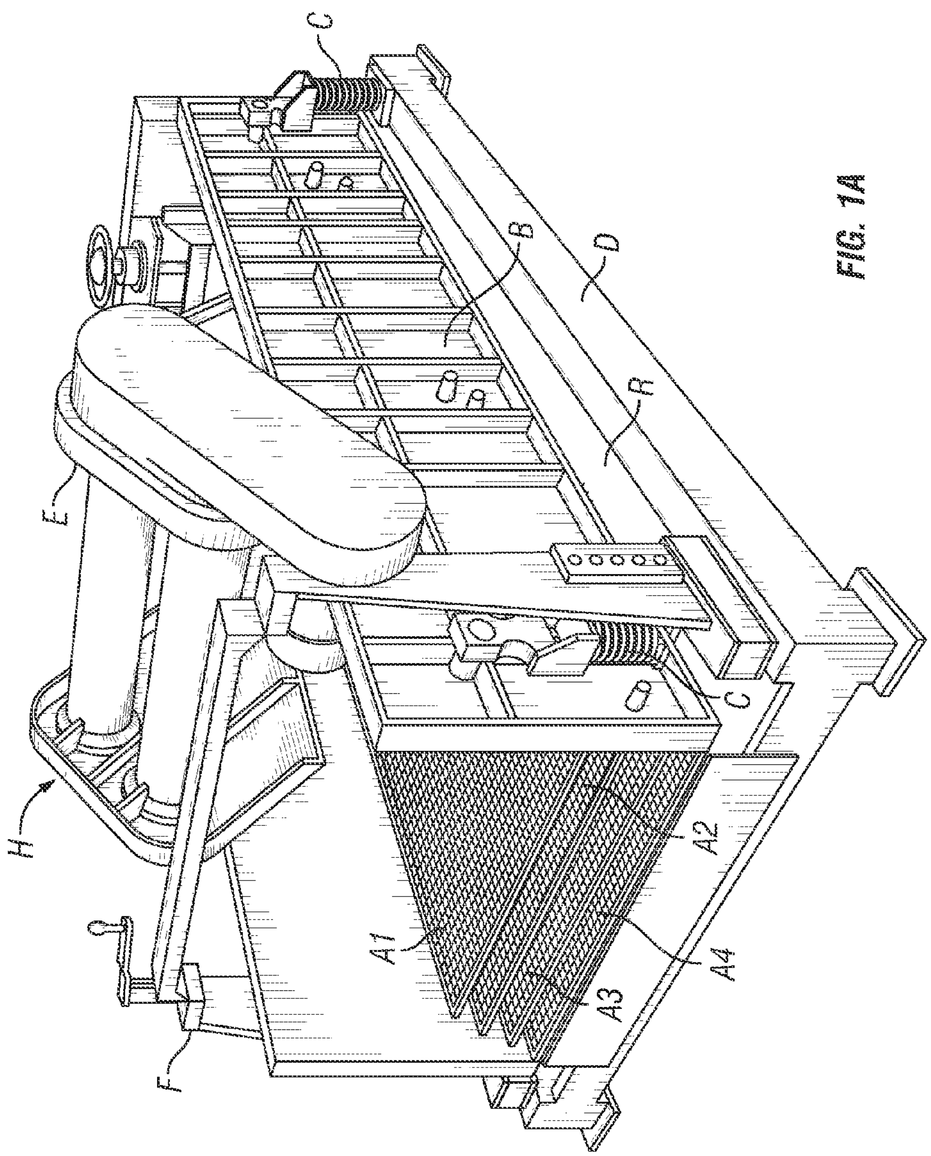


FIG. 1A

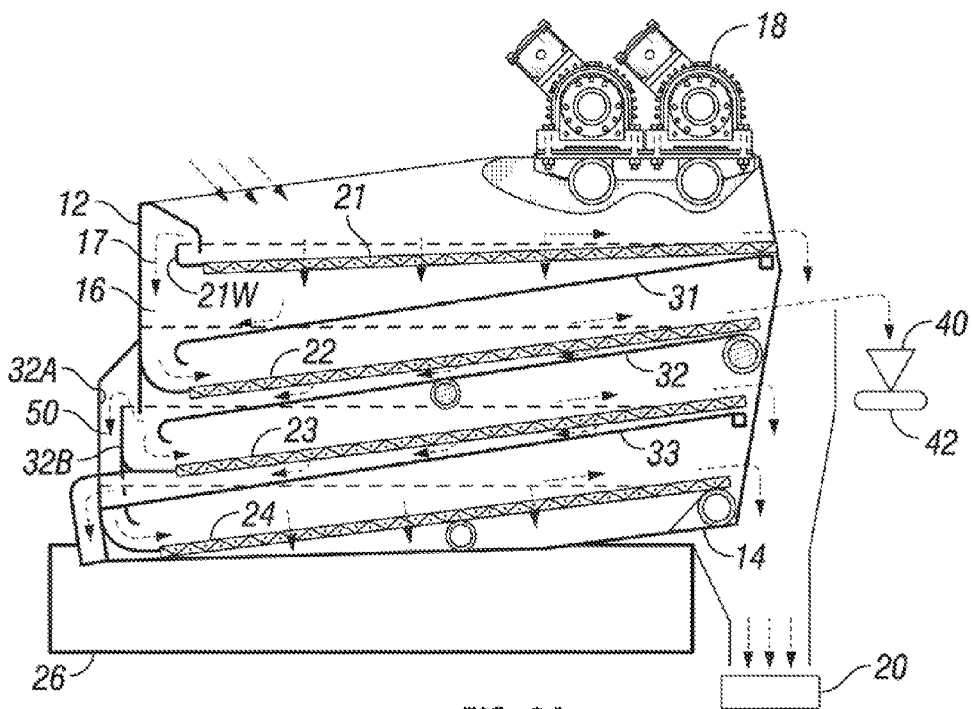

18
12
17
21
16
21W
31
40
32A
22
32
50
42
32B
23
33
24
14
26
20

FIG. 2A

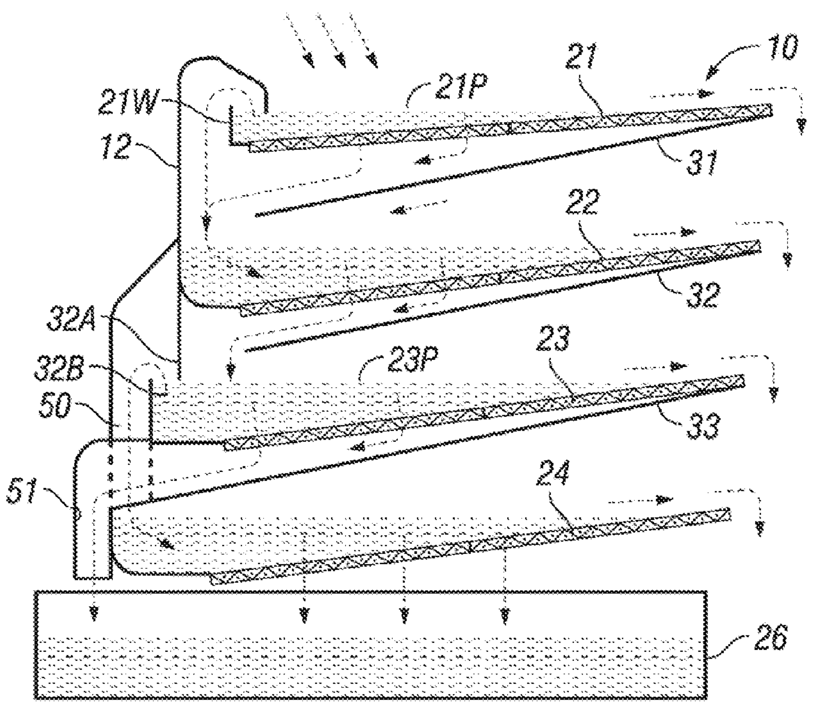

10
21W
21P
21
12
31
22
32
32A
23P
23
32B
50
33
51
24
26

FIG. 2B

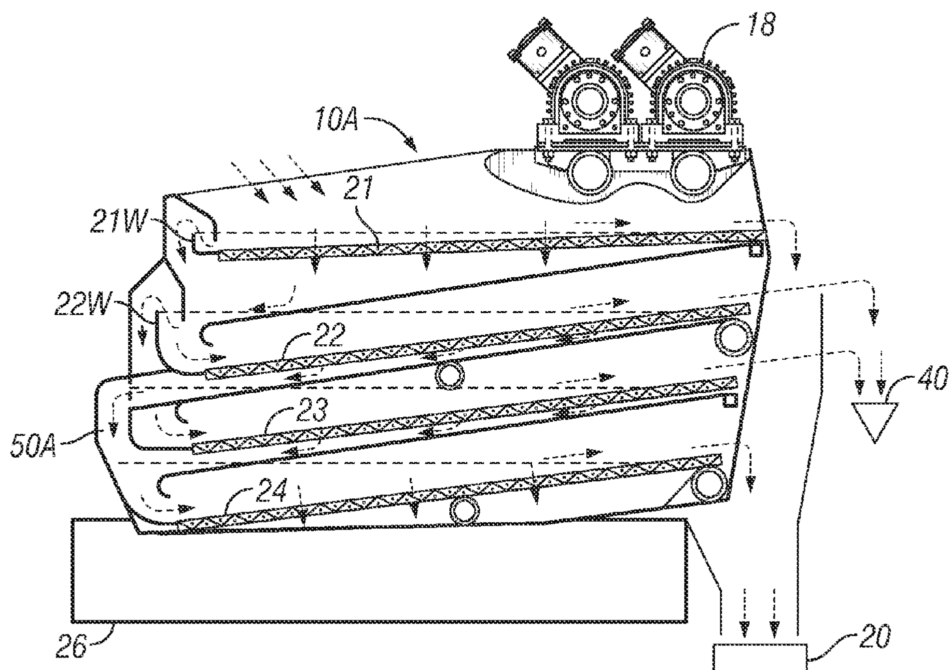
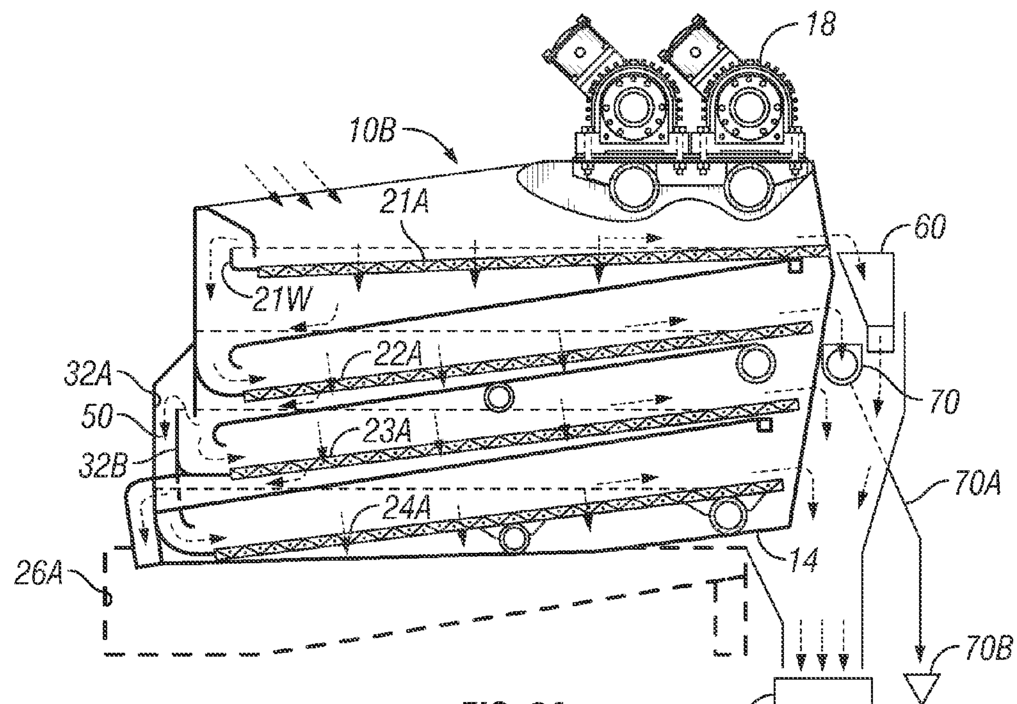
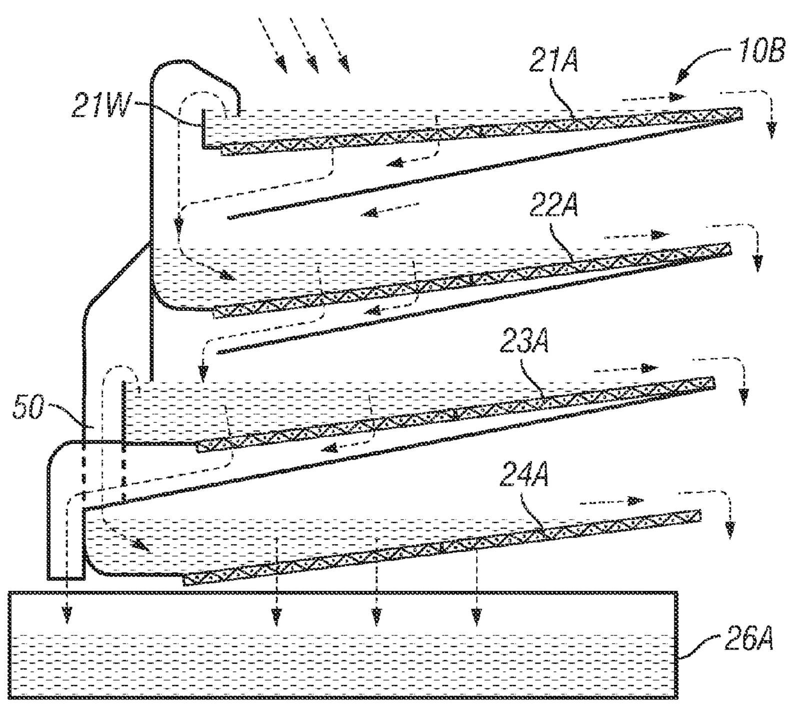


FIG. 2C



18
10B
21A
60
21W
22A
32A
70
50
23A
32B
70A
24A
26A
14
70B
19

FIG. 3A



21A
10B
21W
22A
23A
50
24A
26A

FIG. 3B

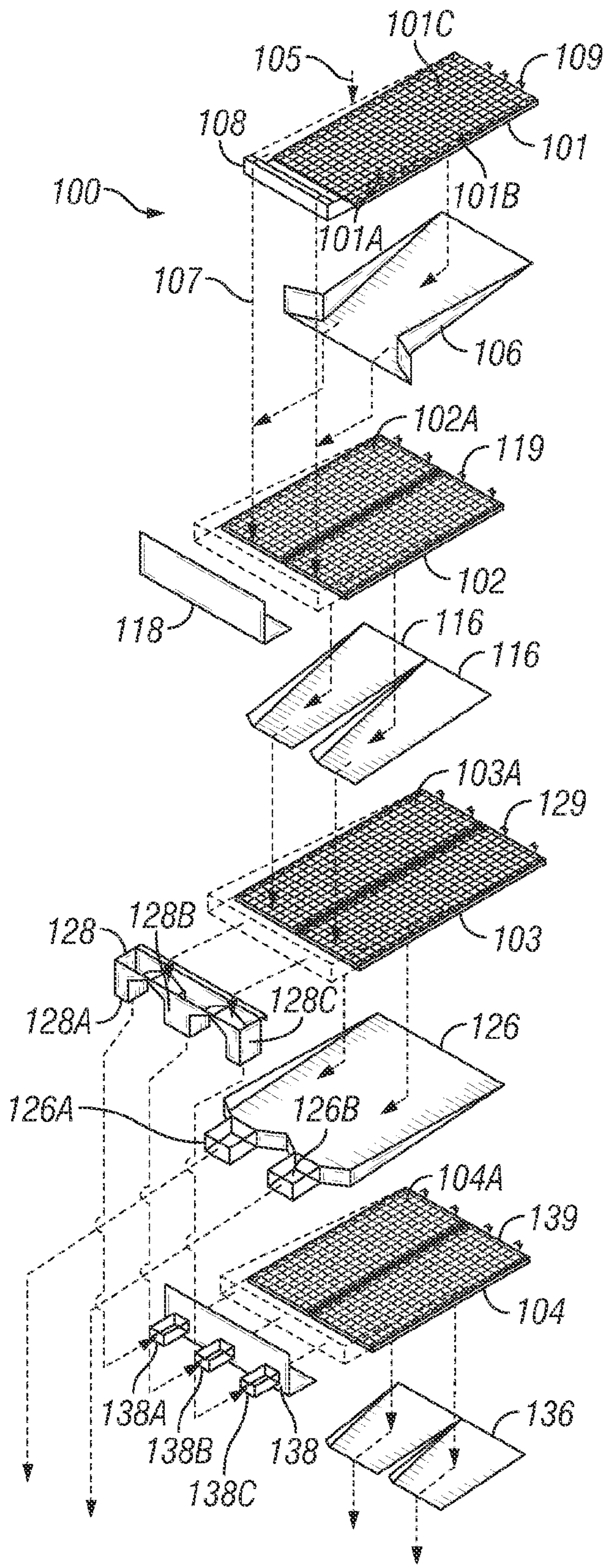

101C
105
109
108
101
100
101B
101A
107
106
102A
119
102
118
116
116
103A
129
128
128B
103
128A
128C
126
126A
126B
104A
139
104
138A
138B
138
136
138C

FIG. 4A

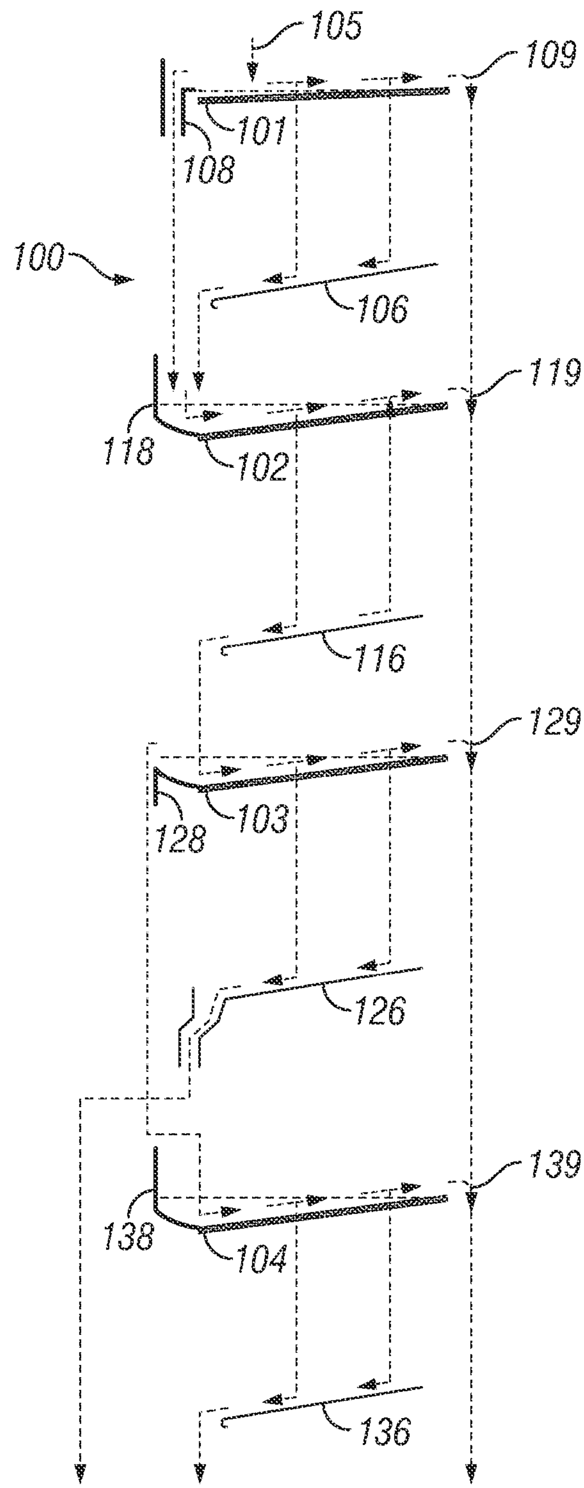

105
109
101
108
100
106
119
118
102
116
129
128
103
126
139
138
104
136

FIG. 4B

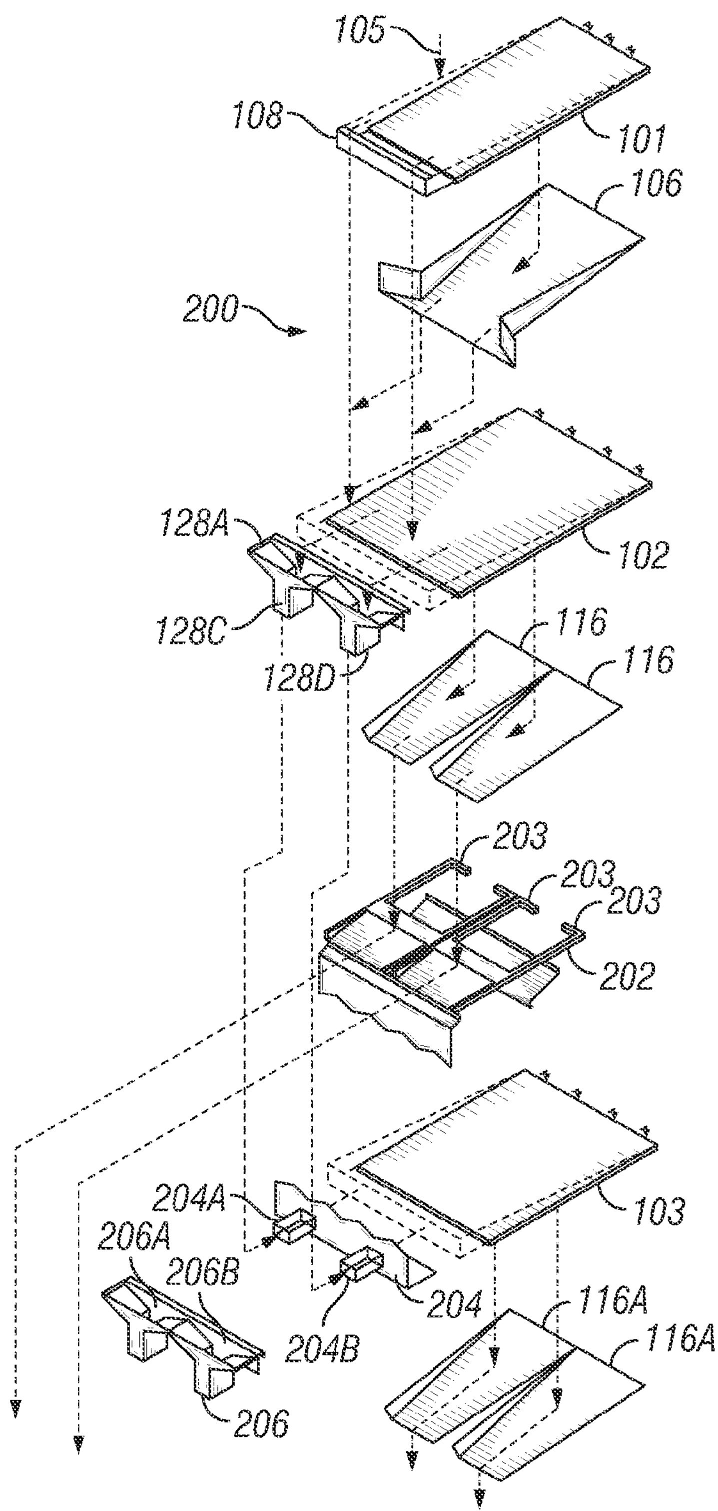

105
108
101
106
200
102
128A
128C
128D
116
116
203
203
203
202
103
204A
206A
206B
204
204B
116A
116A
206

FIG. 5A´

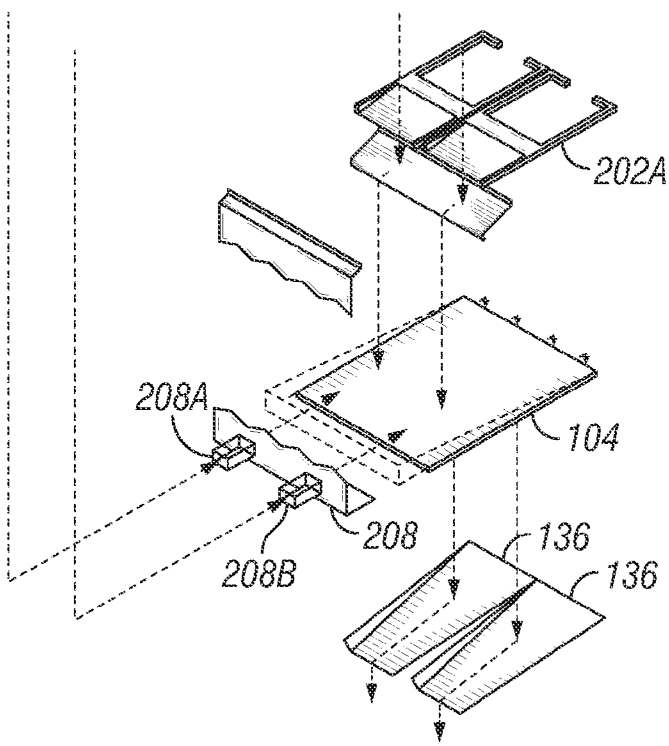


FIG. 5A´´

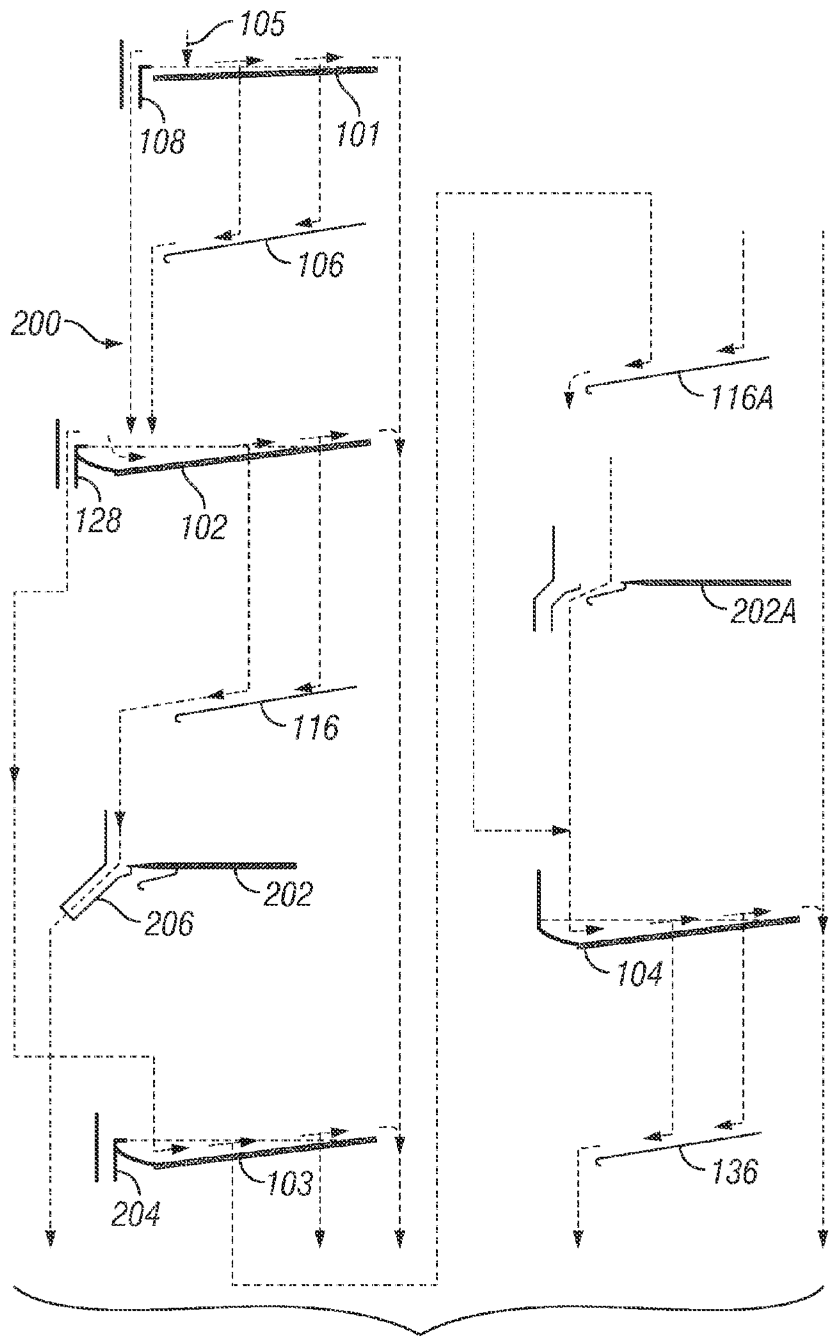

105
108
101
106
200
128
102
116
202
206
204
103
116A
202A
104
136

FIG. 5B

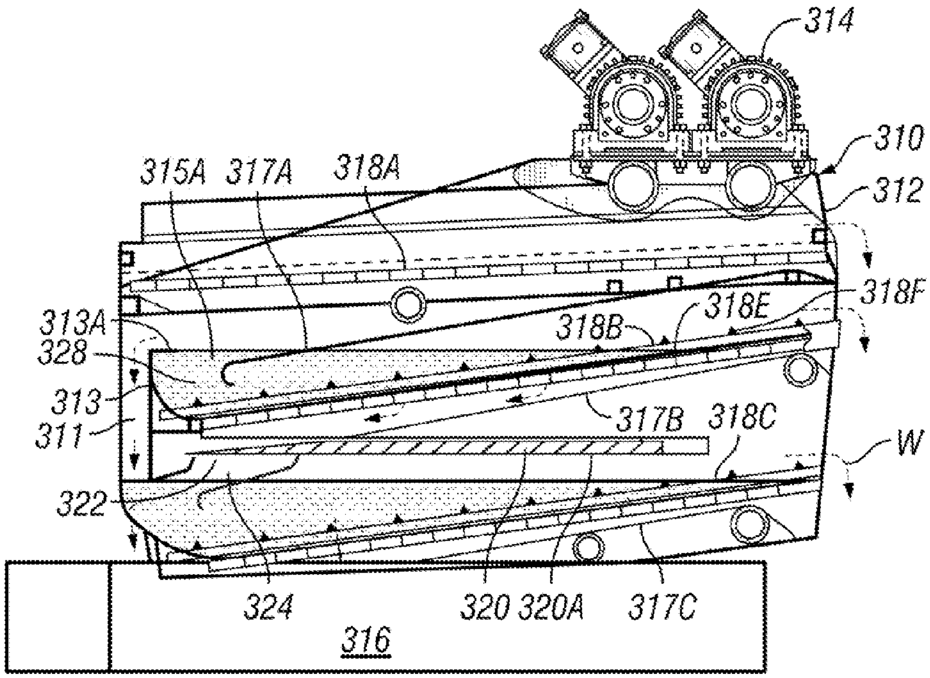

314
310
312
315A
317A
318A
318F
313A
318B
318E
328
313
317B
318C
311
W
322
324
320
320A
317C
316

FIG. 6A

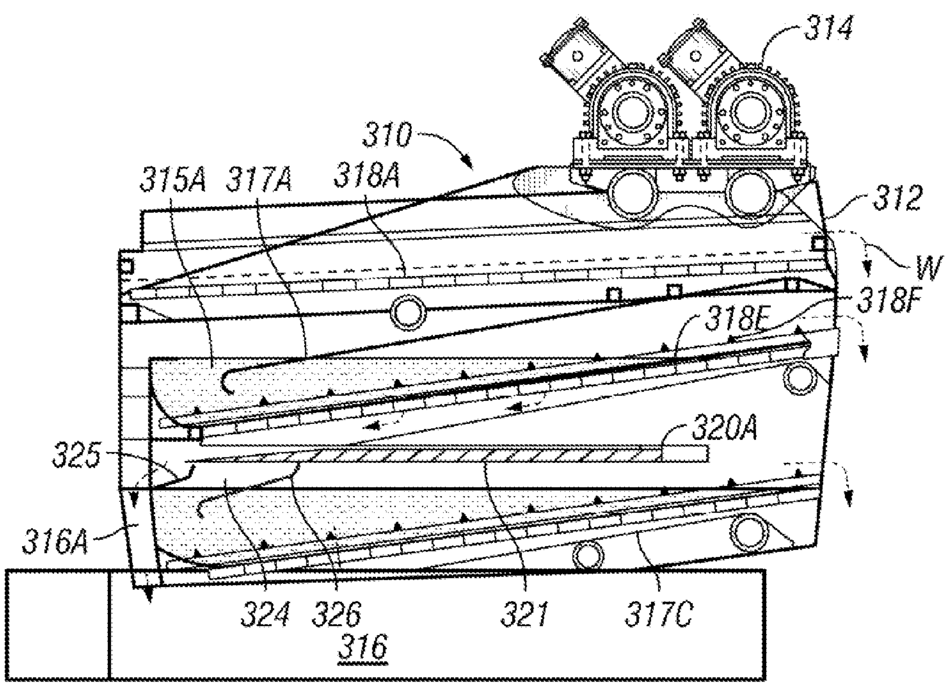

314
310
312
315A
317A
318A
W
318F
318E
320A
325
316A
324
326
321
317C
316

FIG. 6B

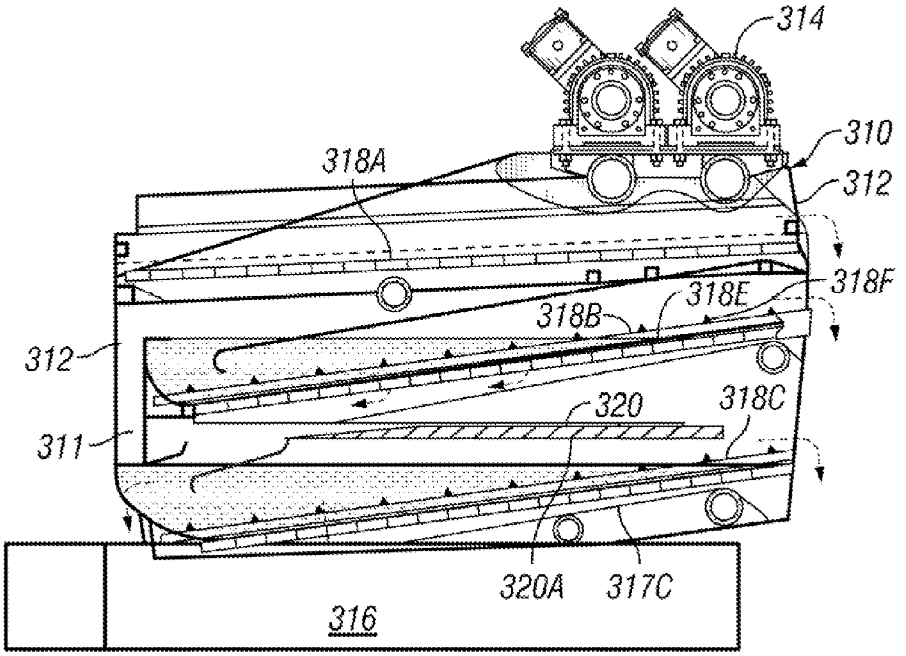

314
310
312
318A
318F
318B
318E
312
320
318C
311
320A
317C
316

FIG. 6C

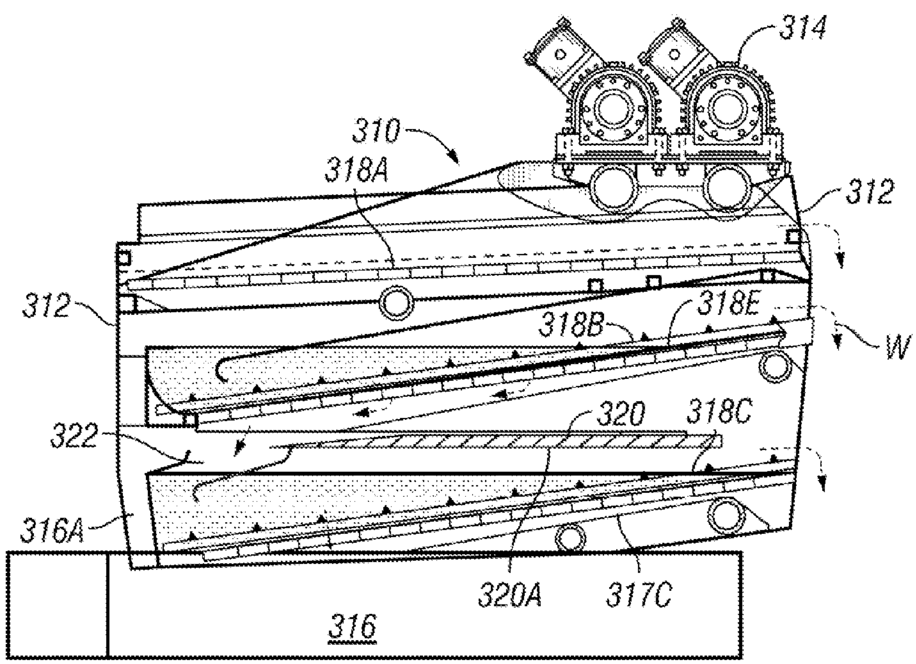

314
310
318A
312
312
318B
318E
W
320
318C
322
316A
320A
317C
316

FIG. 6D

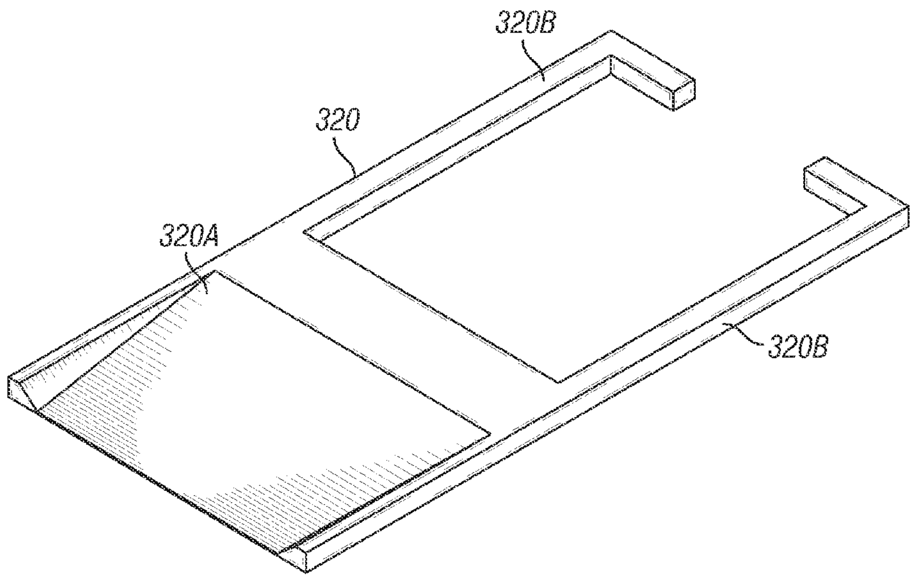


FIG. 6E

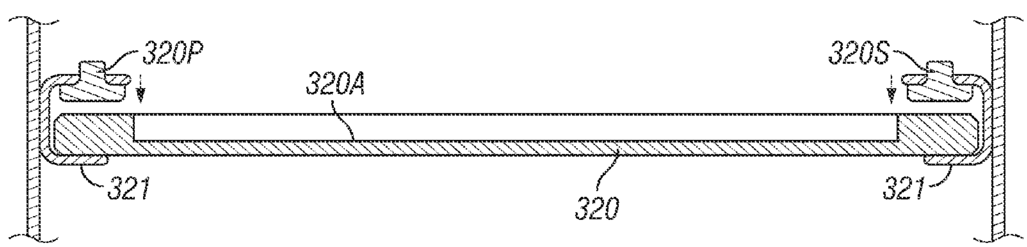


FIG. 6G

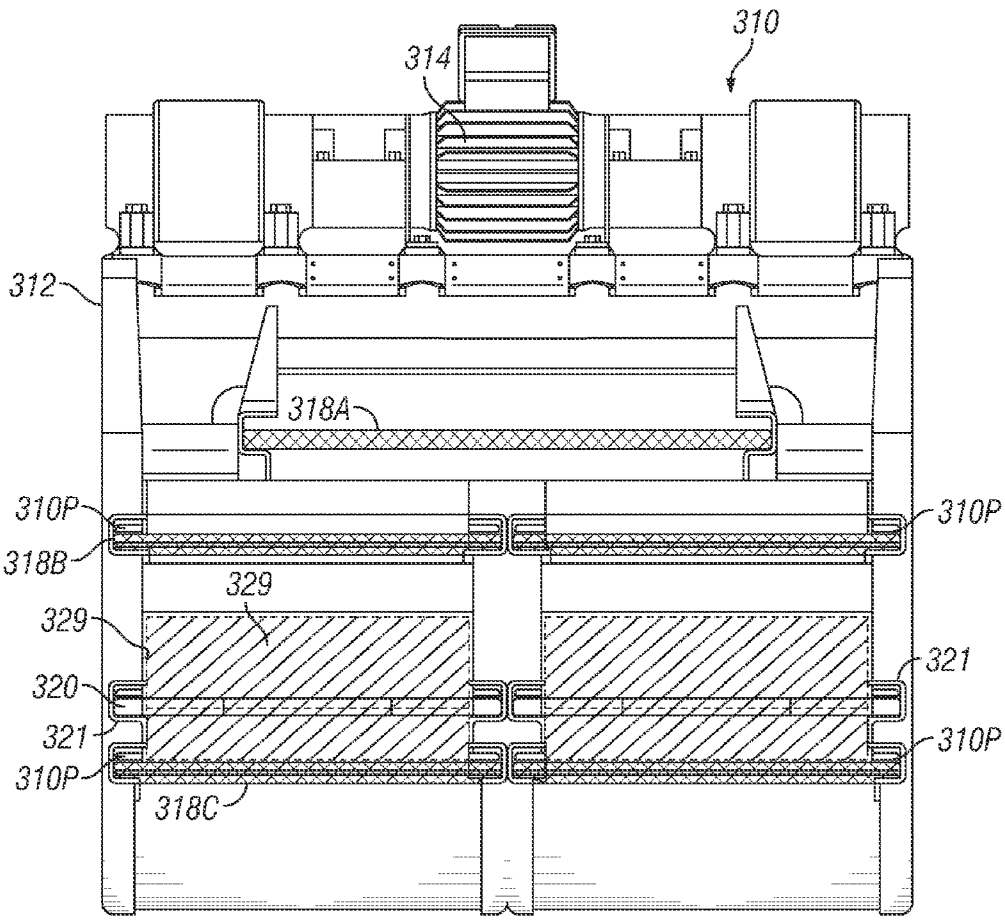
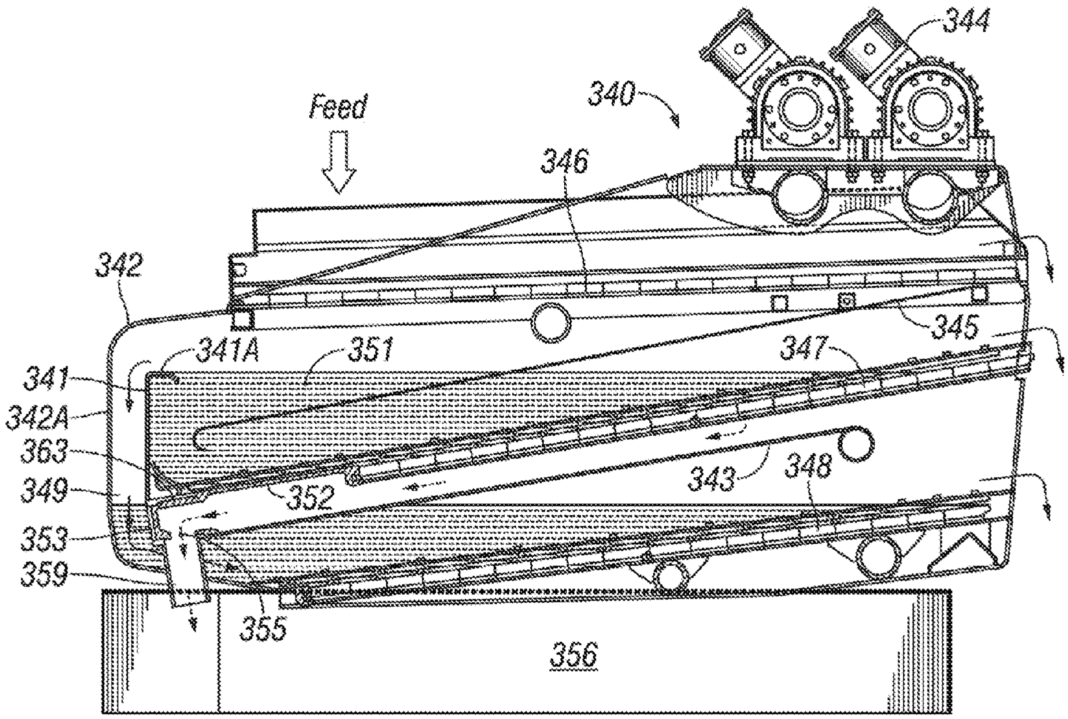
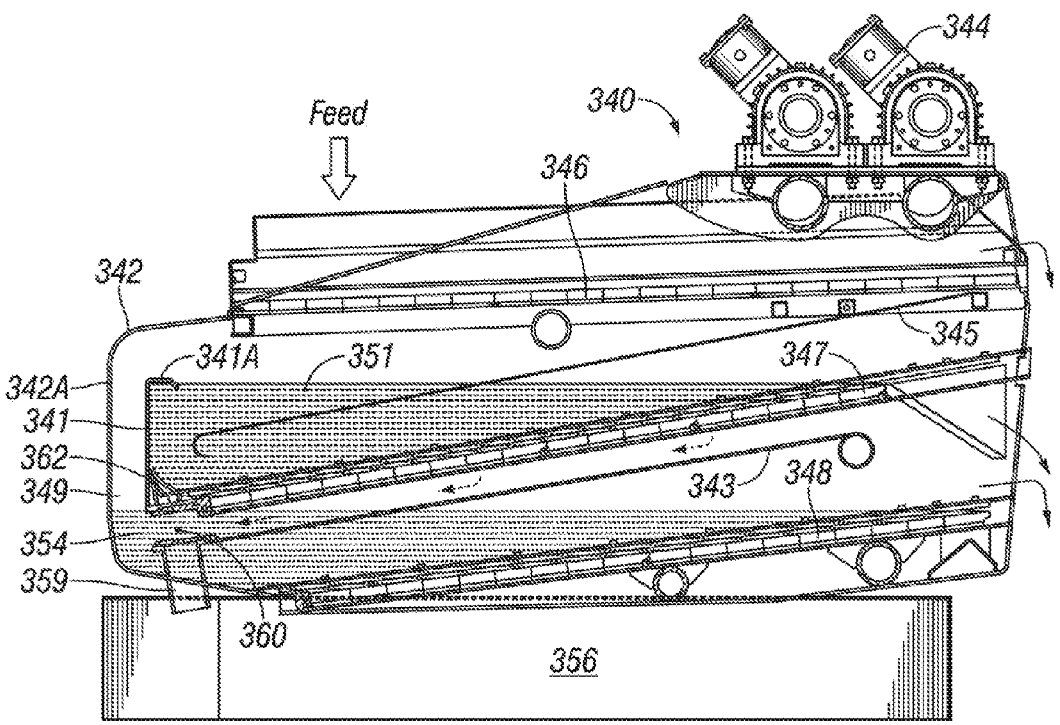

310
314
312
318A
310P
310P
318B
329
329
321
320
321
310P
310P
318C

FIG. 6F



344
340
Feed
346
342
345
341A
351
347
341
342A
363
343
348
349
352
353
359
355
356

FIG. 7A



344
340
Feed
346
342
345
341A
351
347
342A
341
362
343
348
349
354
359
360
356

FIG. 7B

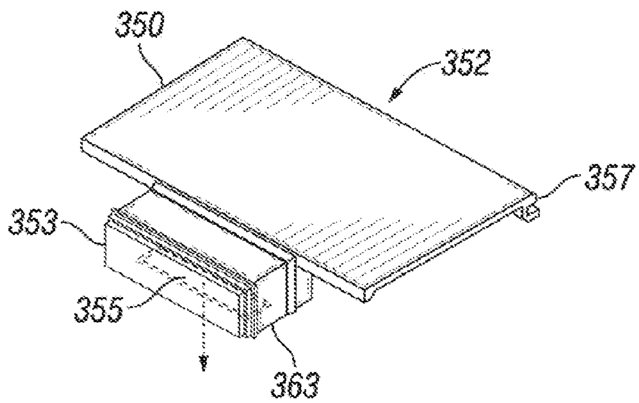


FIG. 7C

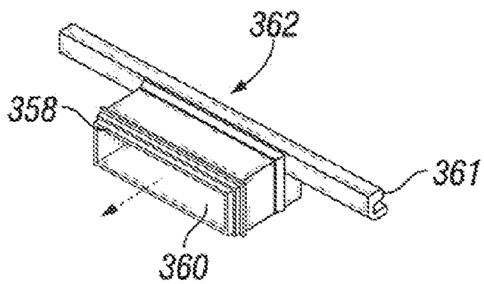


FIG. 7D

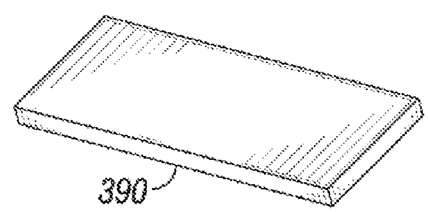


FIG. 8C

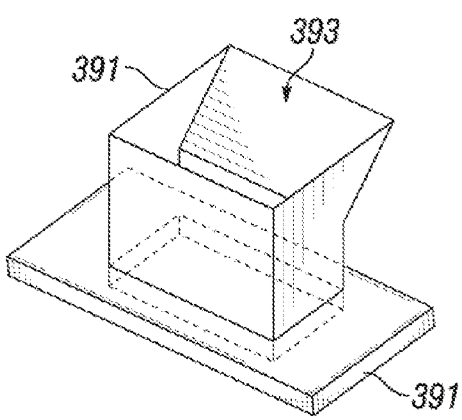


FIG. 8D

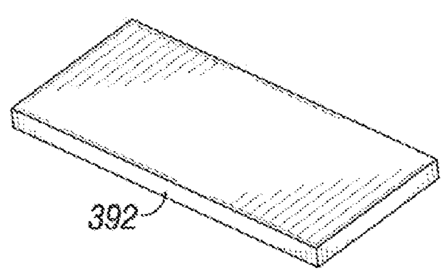


FIG. 8E

FIG. 8A

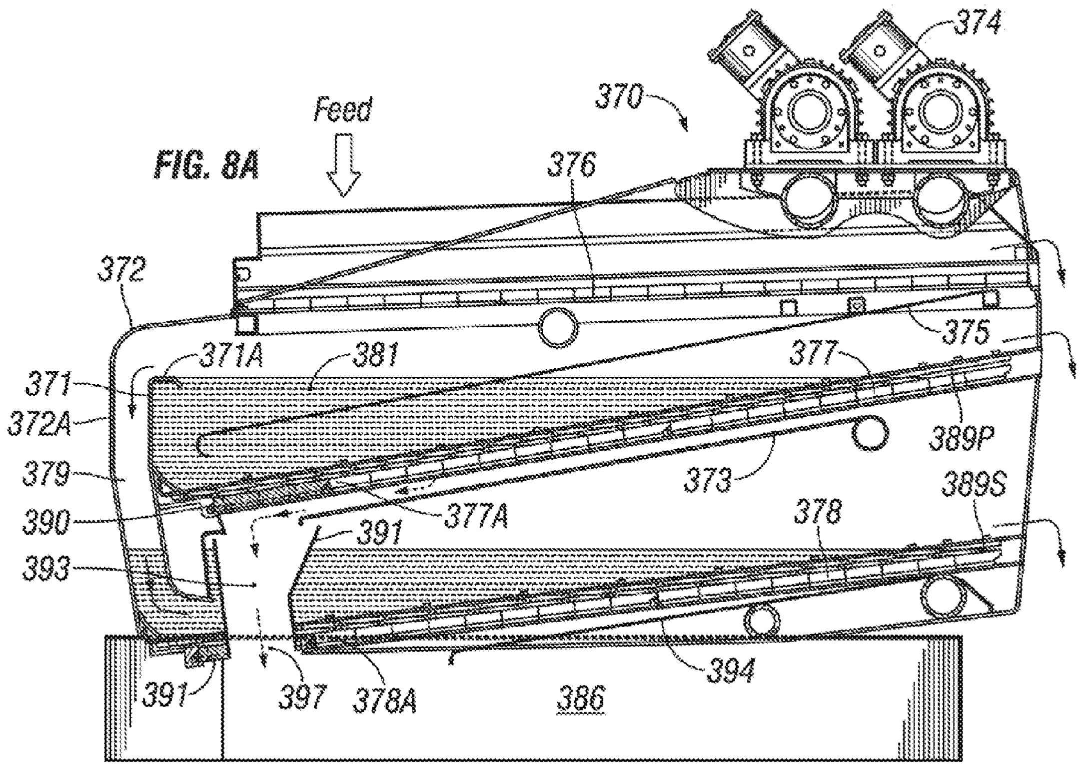
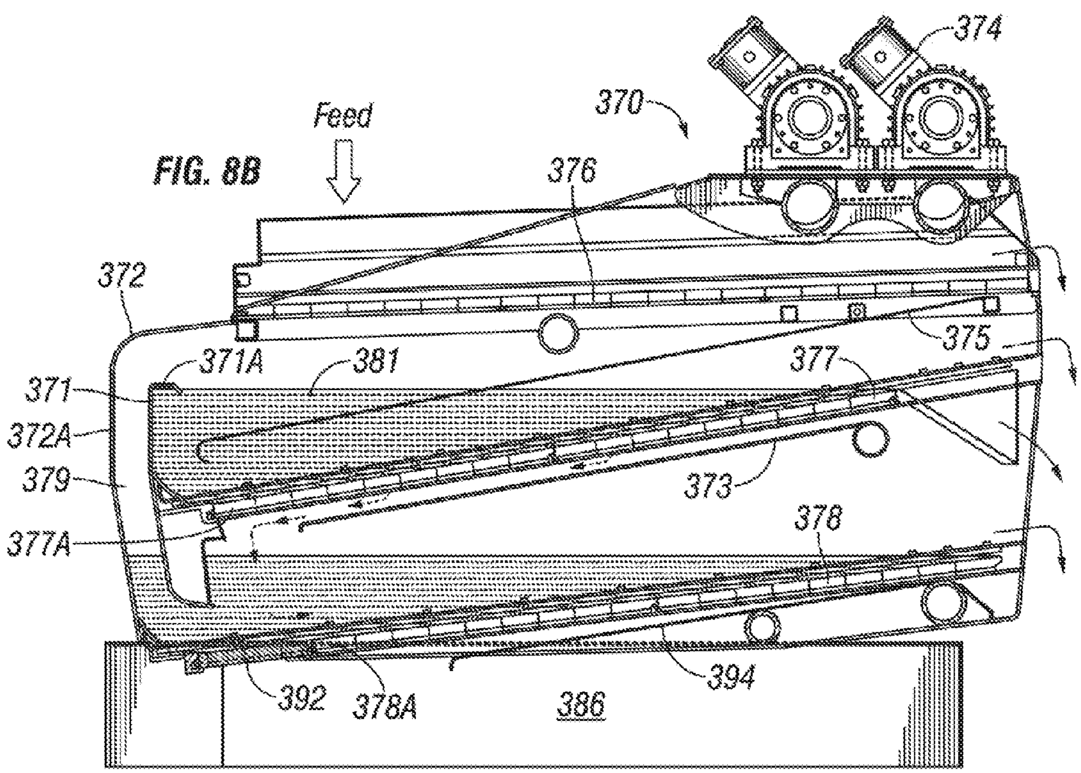

Feed
370
374
376
372
375
371A
381
377
371
372A
389P
379
373
389S
390
377A
391
378
393
391
397
378A
386
394

FIG. 8B


Feed
370
374
376
372
375
371A
381
377
371
372A
379
373
378
377A
392
378A
386
394

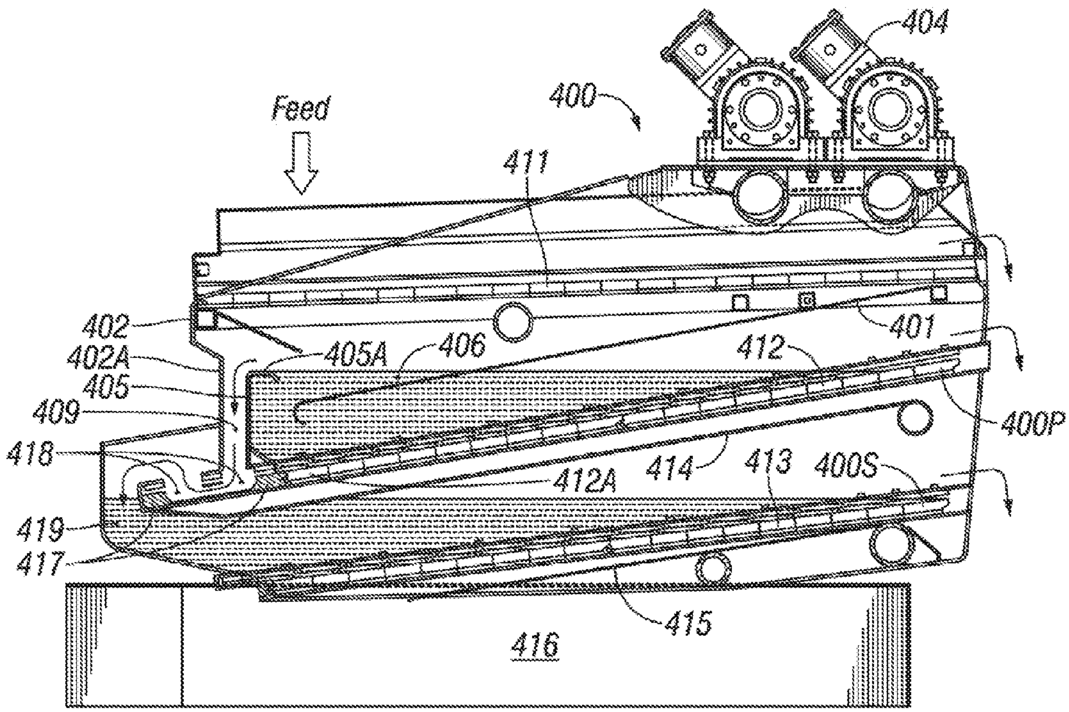

404
400
Feed
411
402
401
402A
405A
406
412
405
409
400P
418
412A
414
413
400S
419
417
415
416

FIG. 9A

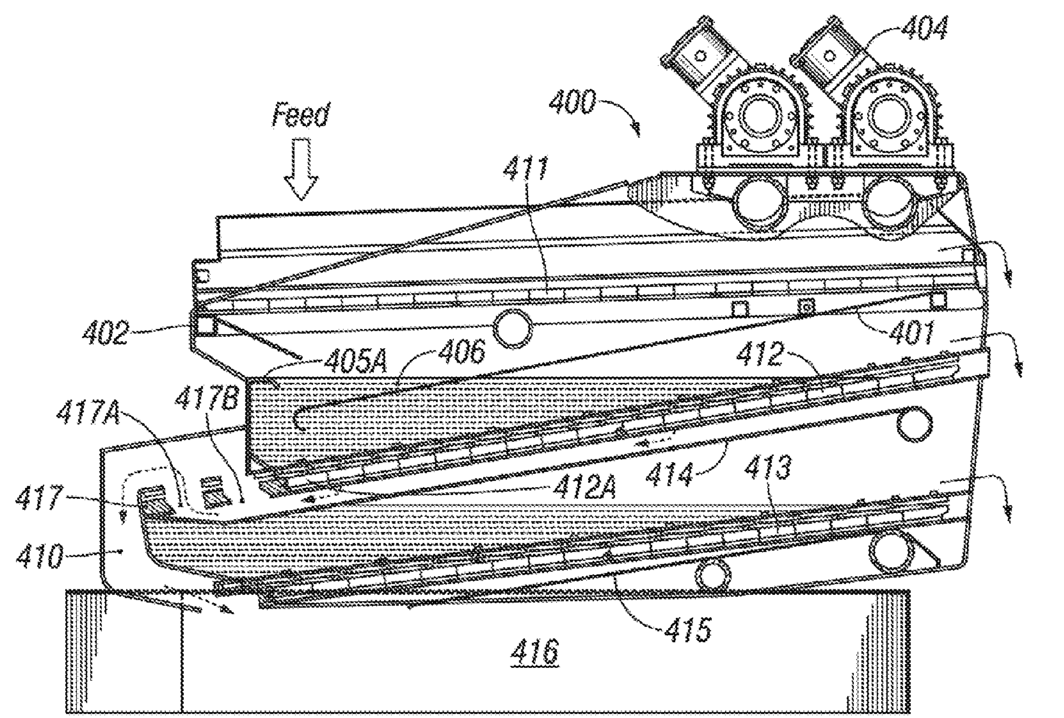
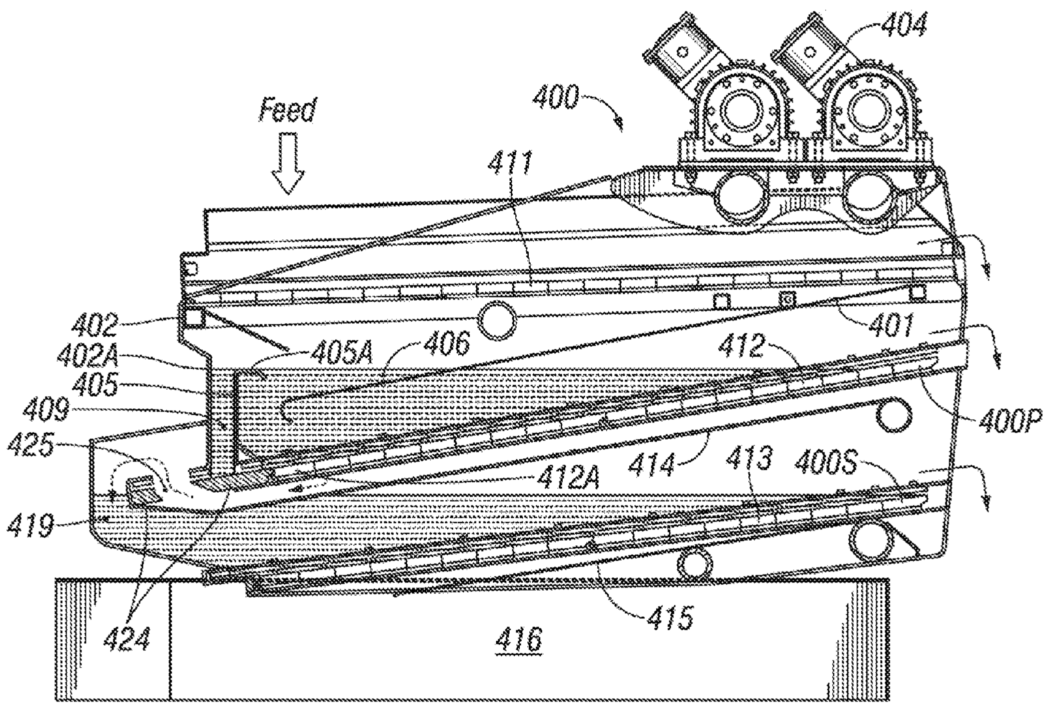
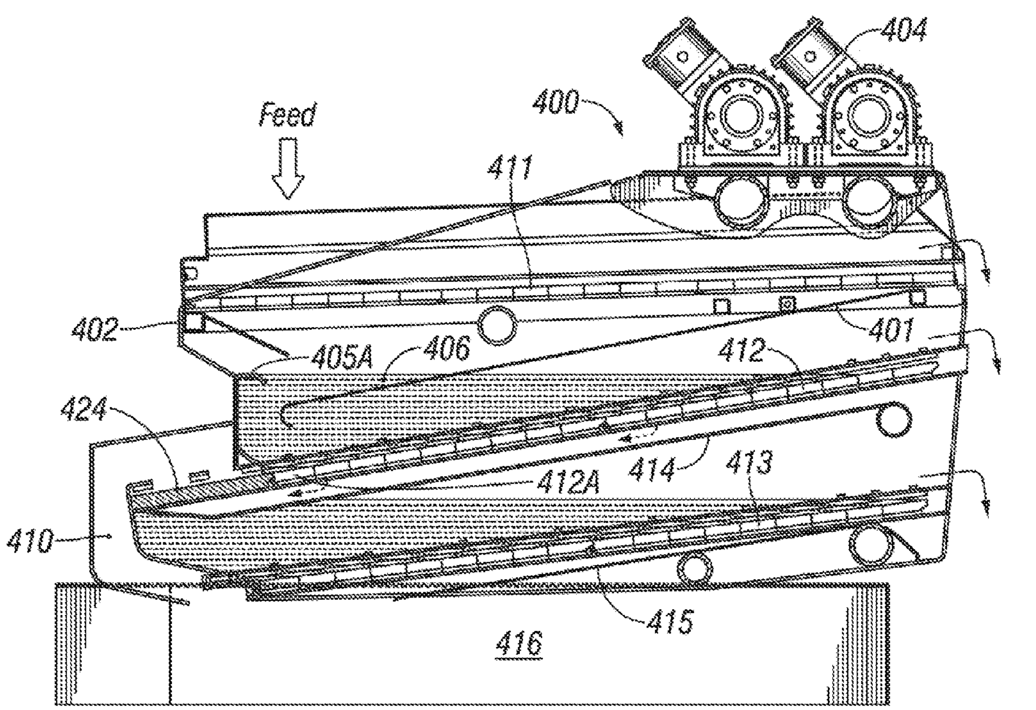

404
400
Feed
411
402
401
405A
406
412
417A
417B
414
413
412A
417
410
415
416

FIG. 9B



Feed
400
404
411
402
402A
405
409
425
419
424
405A
406
412
401
400P
414
412A
413
400S
415
416

FIG. 9C



Feed
400
404
411
402
424
410
405A
406
412
401
414
412A
413
415
416

FIG. 9D

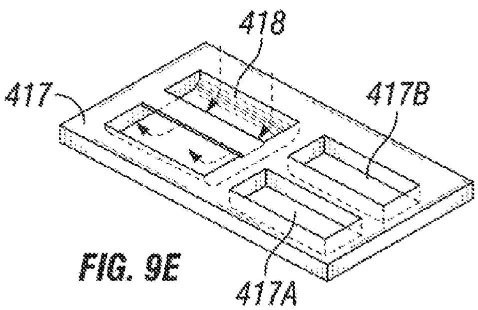


FIG. 9E

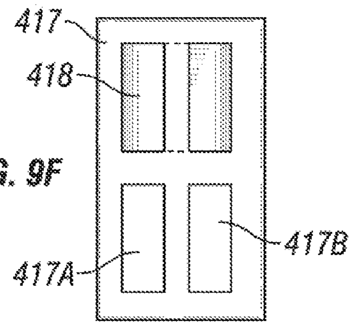


FIG. 9F

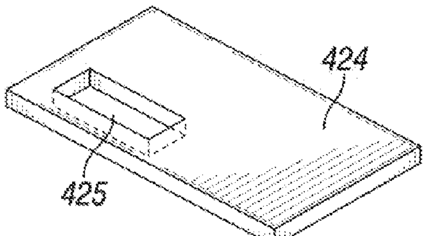


FIG. 9G

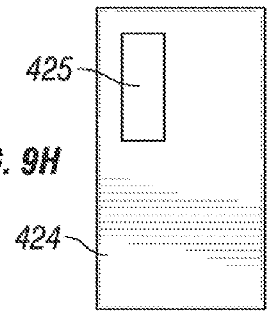


FIG. 9H

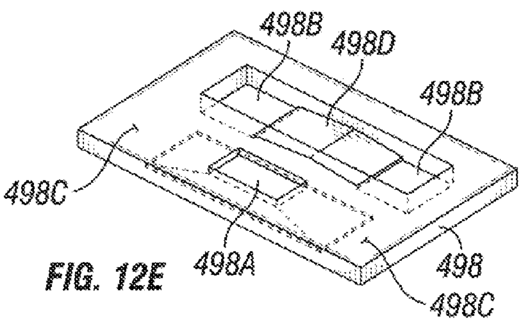


FIG. 12E

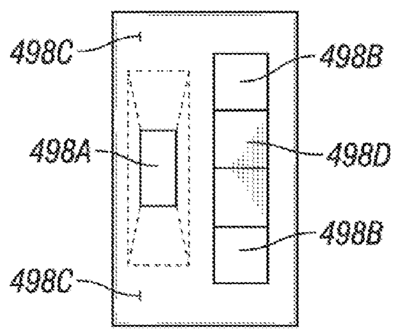


FIG. 12F

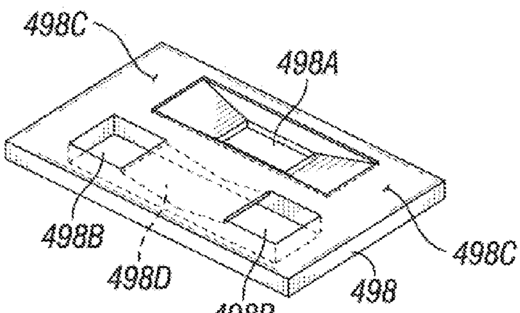


FIG. 12G

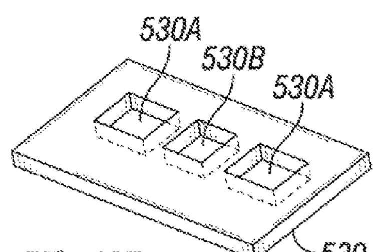


FIG. 13E

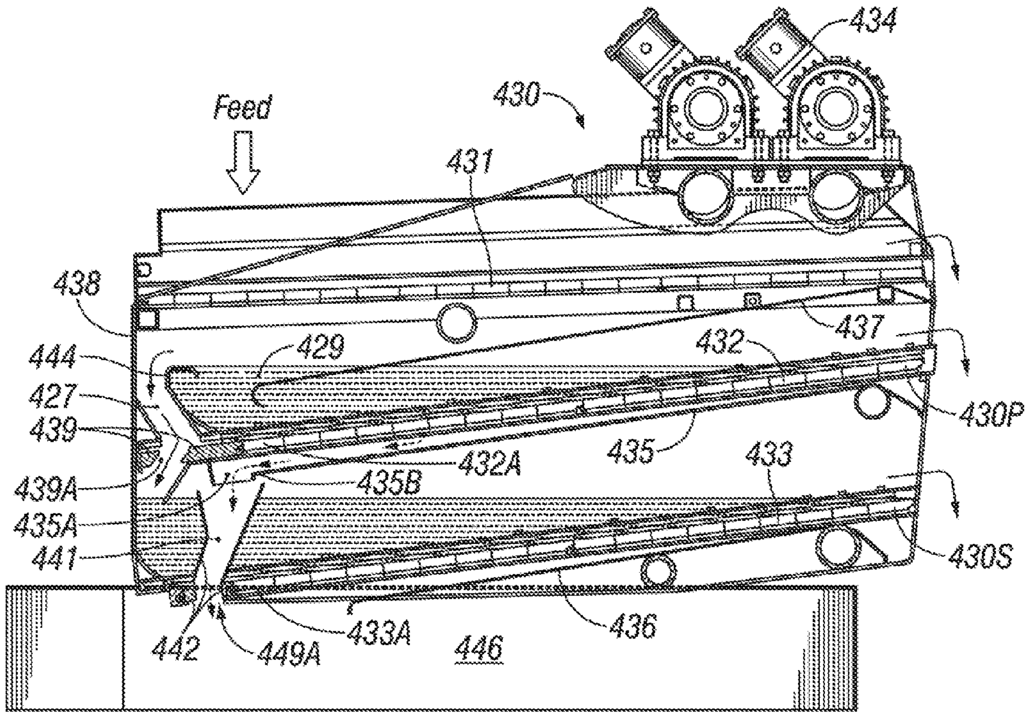


FIG. 10A

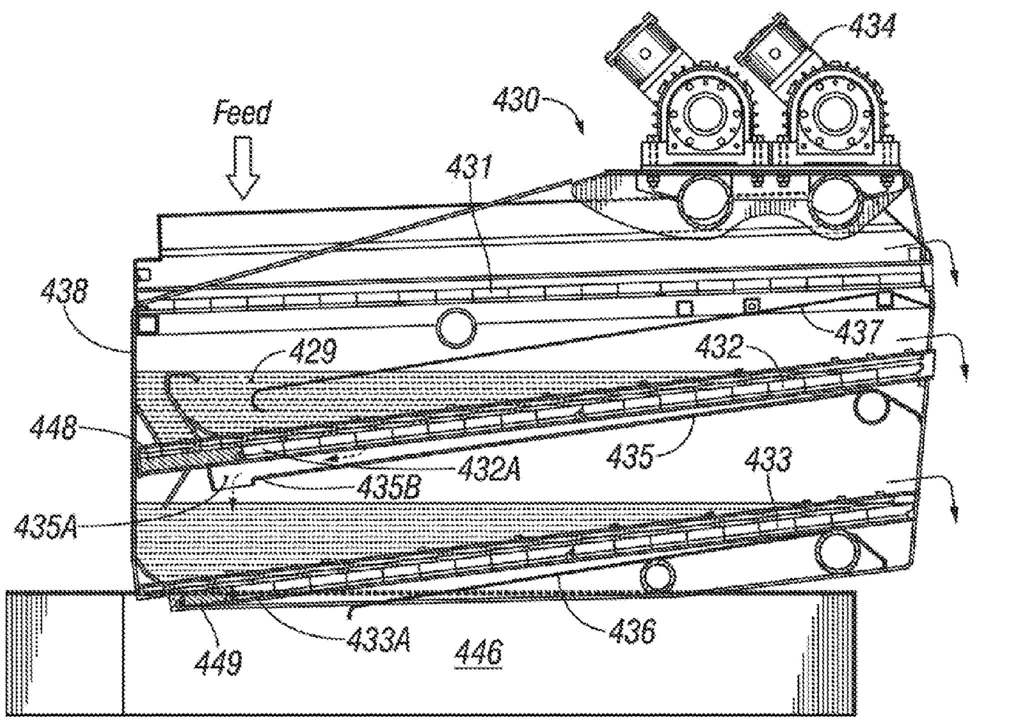


FIG. 10B

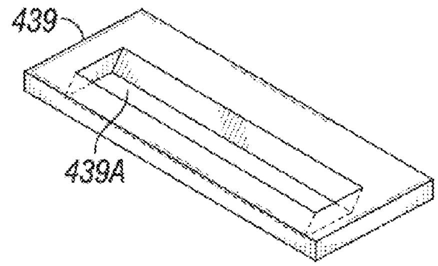


FIG. 10C

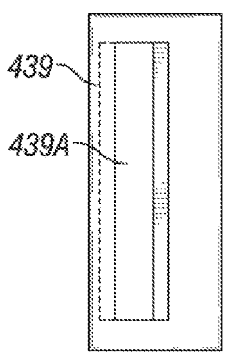


FIG. 10D

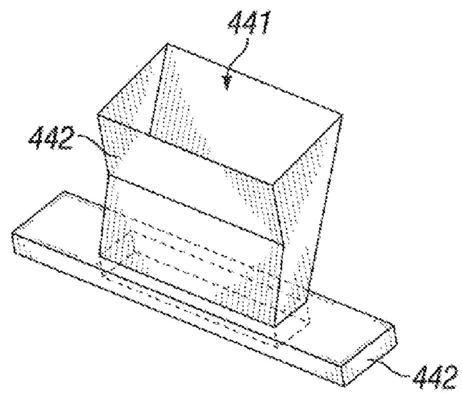


FIG. 10E

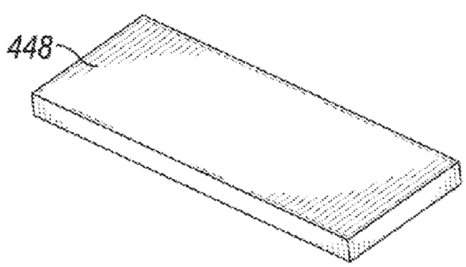


FIG. 10F

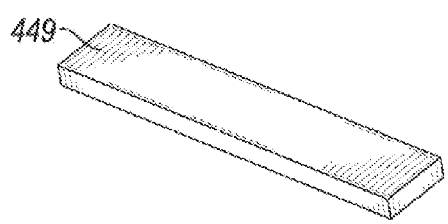


FIG. 10G

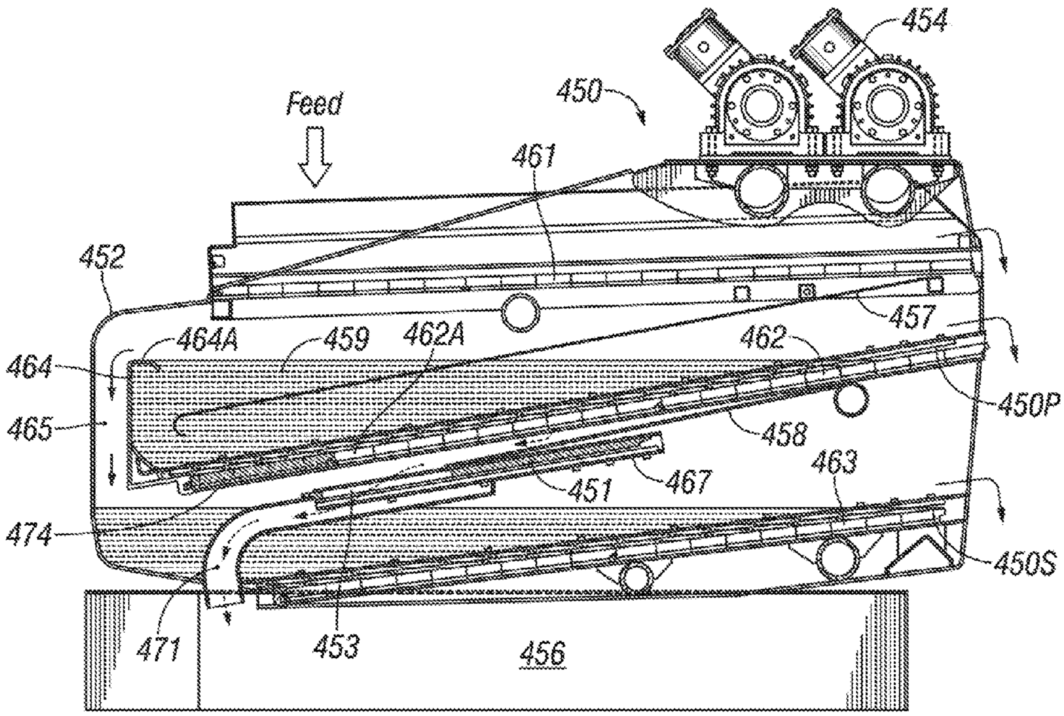


FIG. 11A

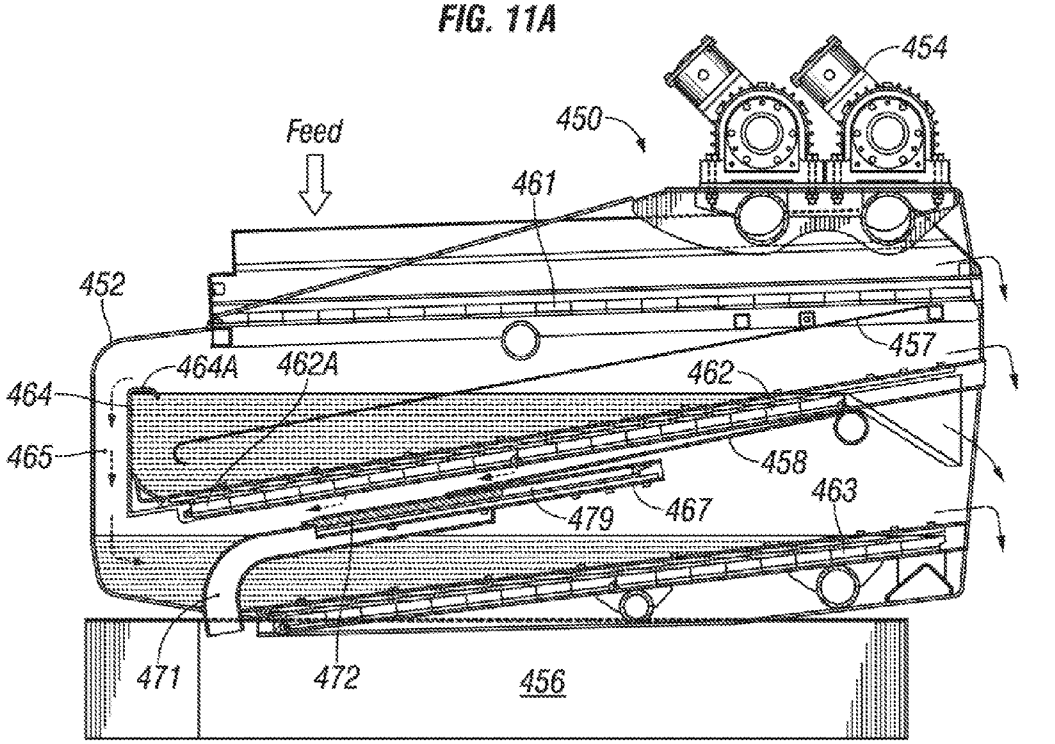


FIG. 11B

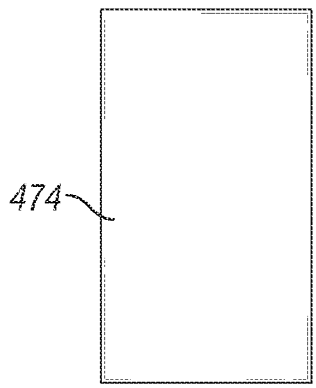


FIG. 11C

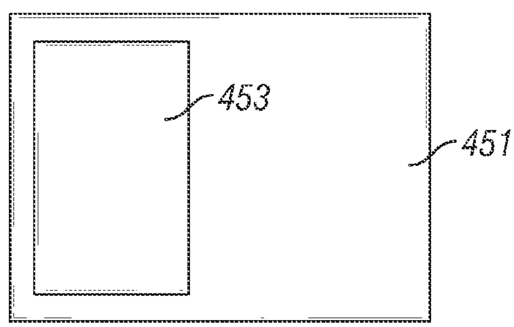


FIG. 11D

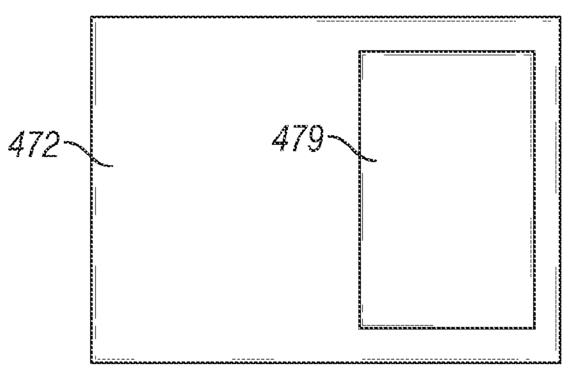


FIG. 11E

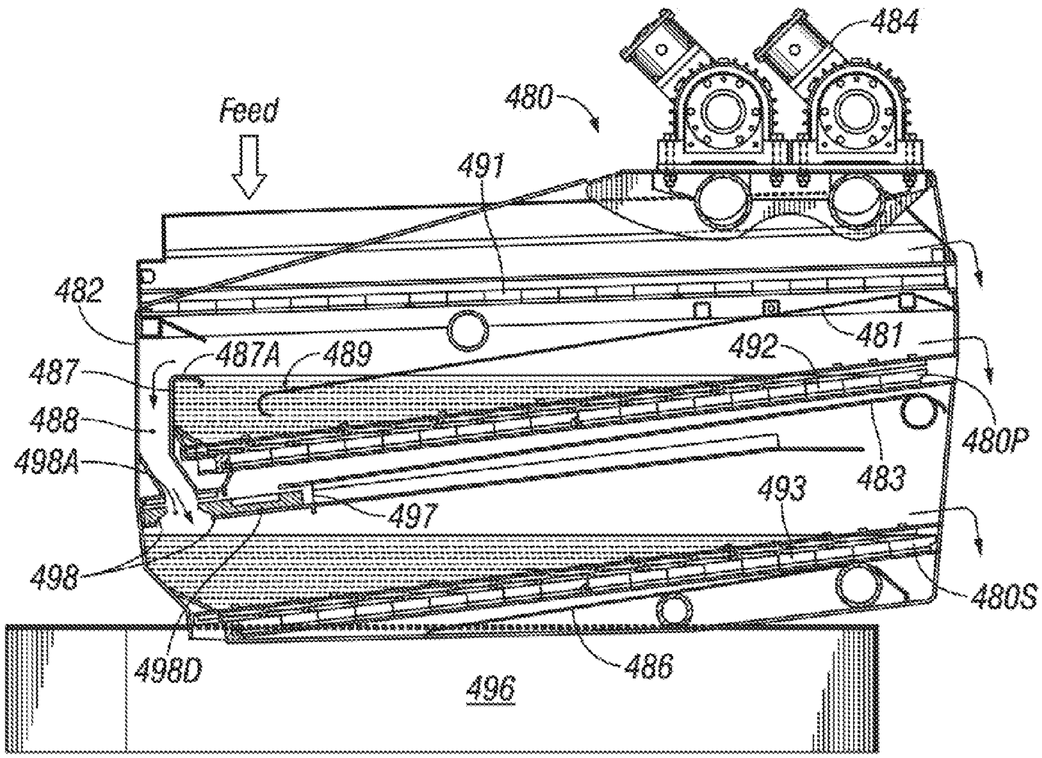


FIG. 12A

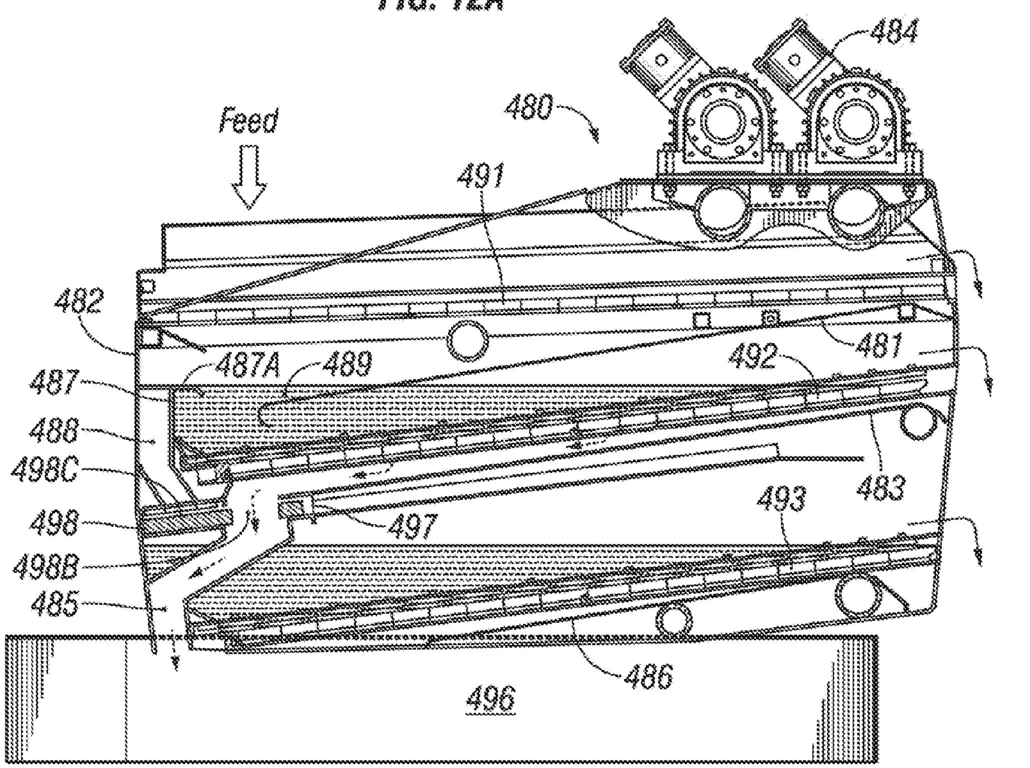


FIG. 12B

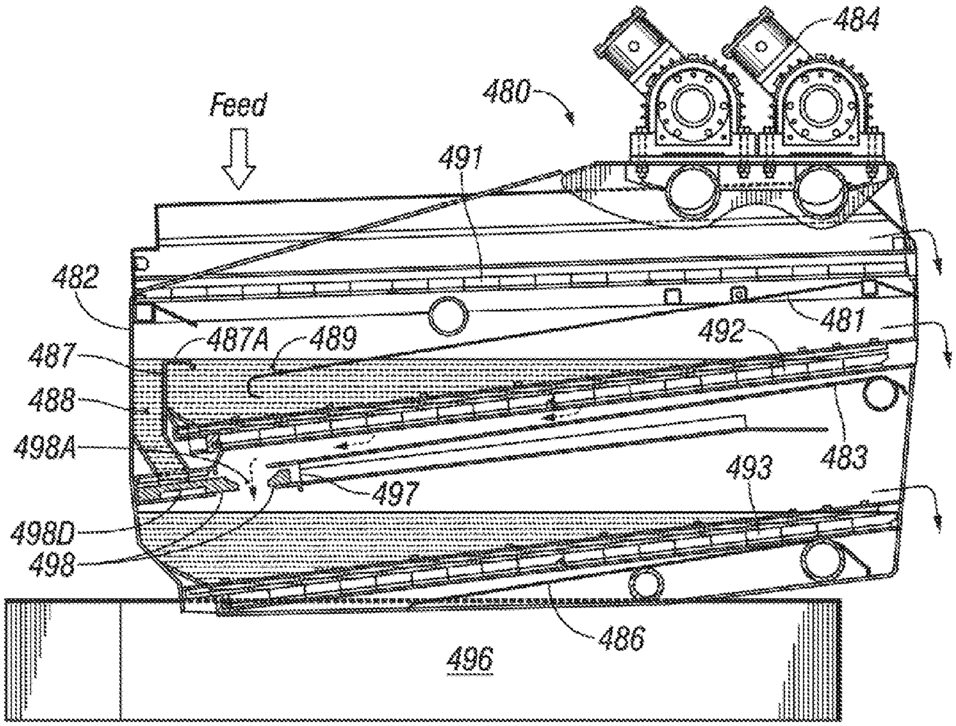


FIG. 12C

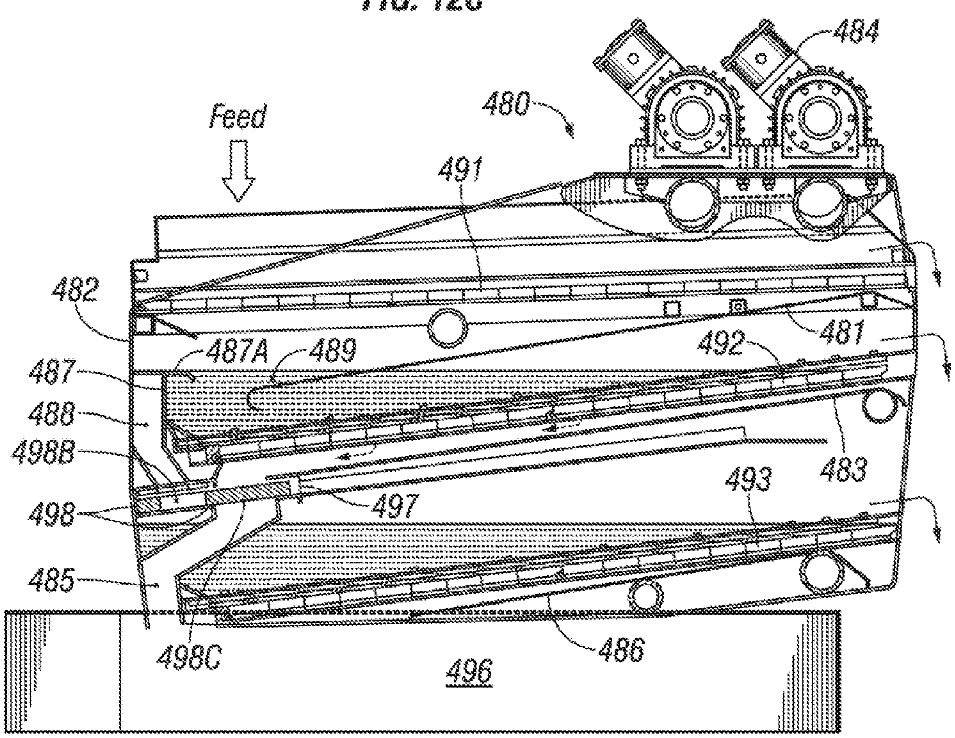


FIG. 12D

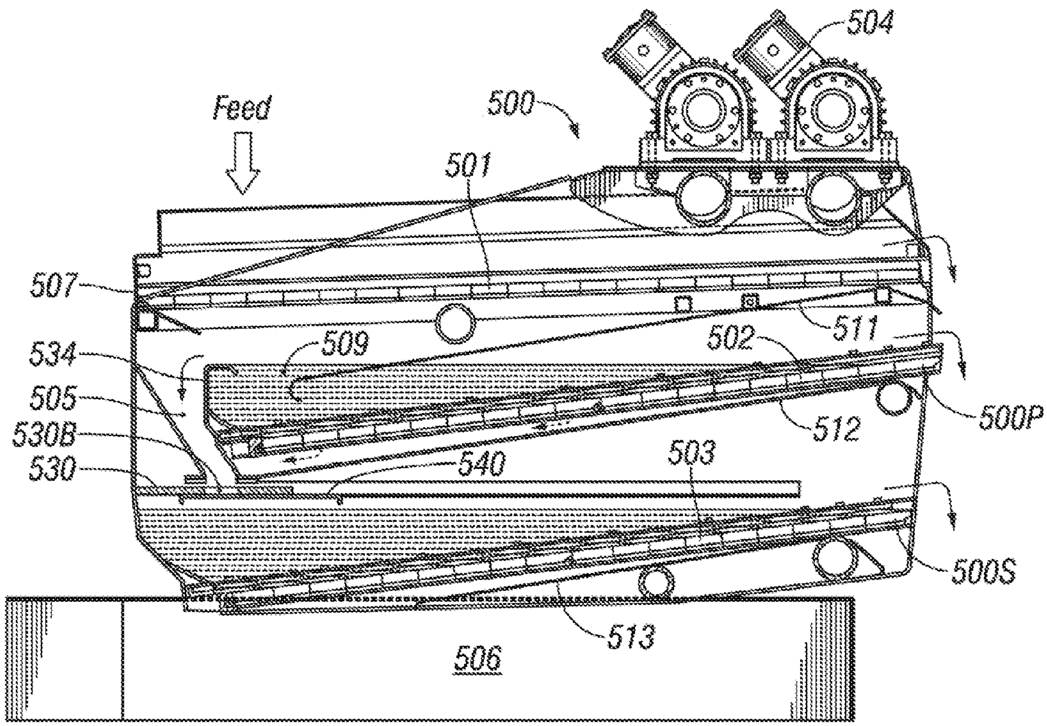


FIG. 13A

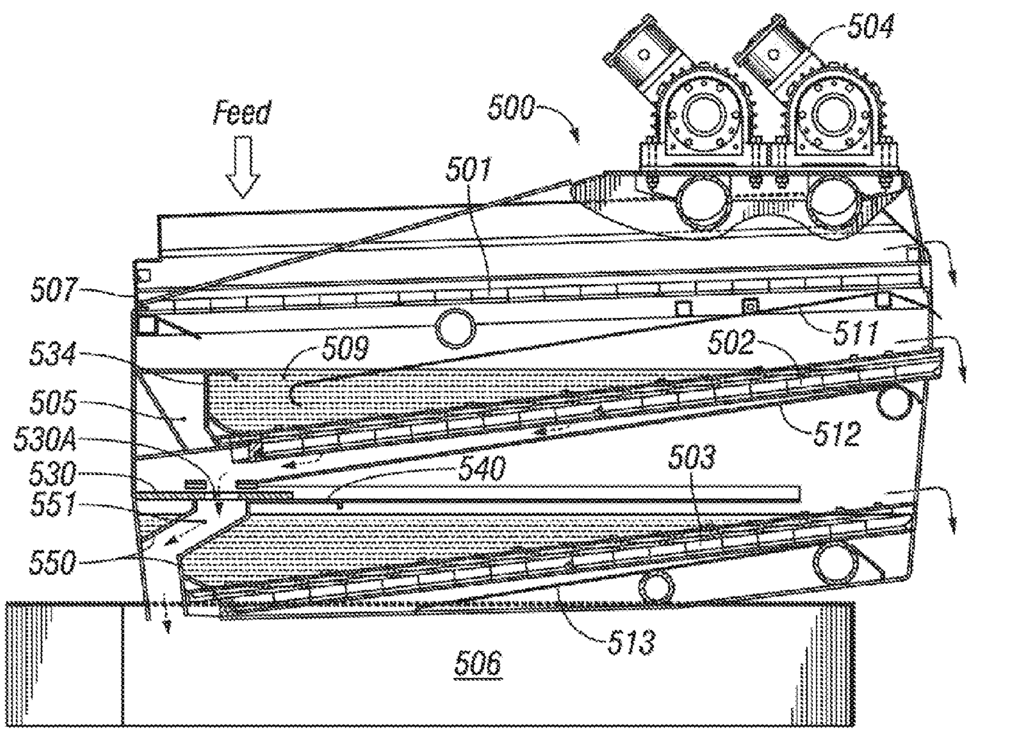


FIG. 13B

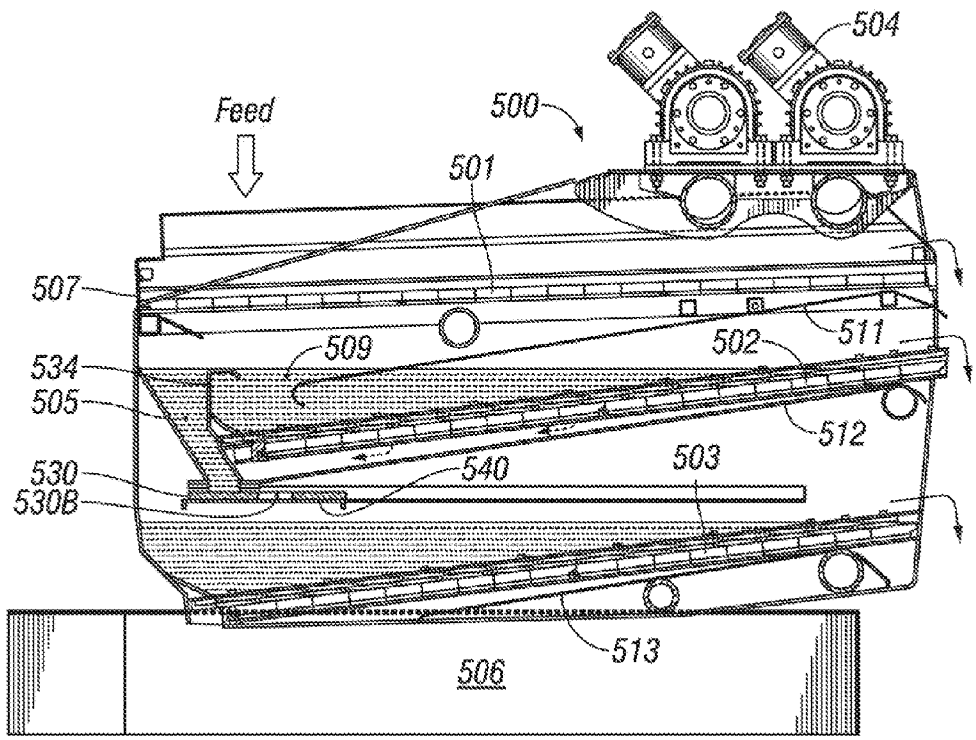


FIG. 13C

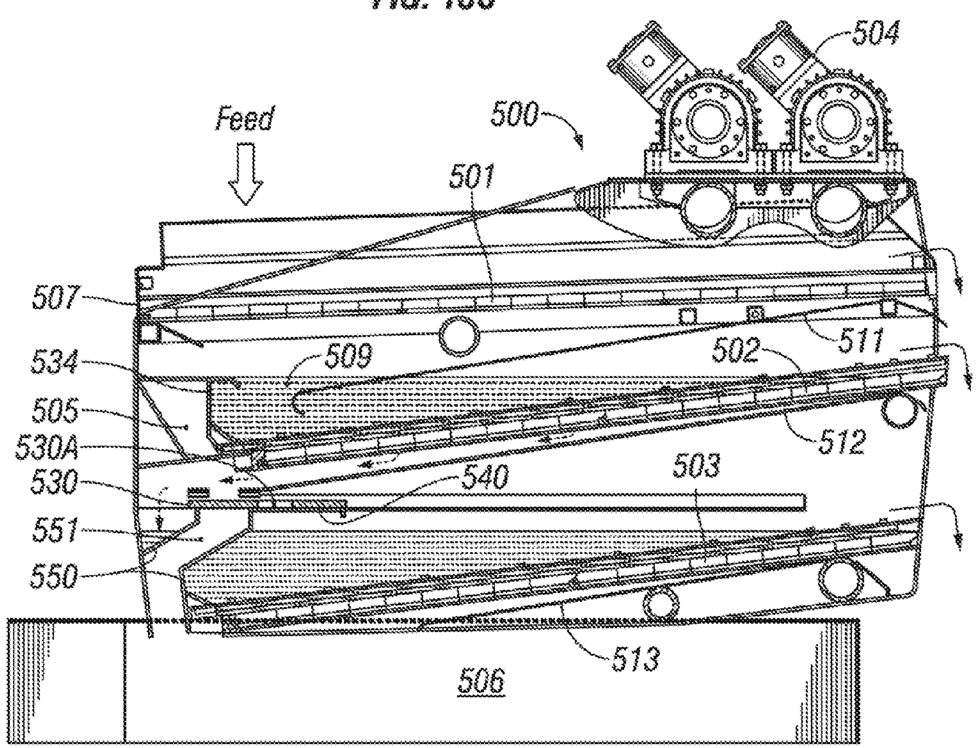


FIG. 13D

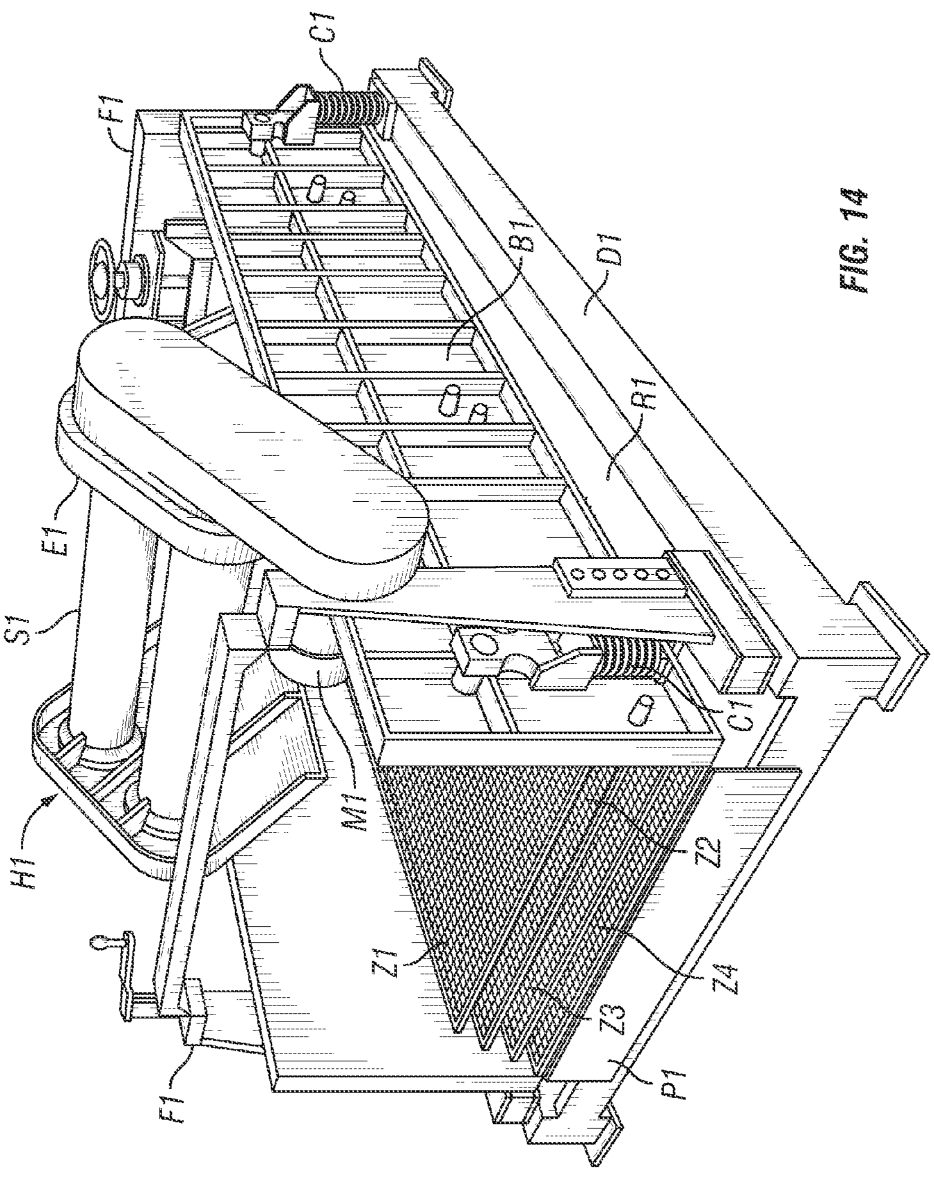


FIG. 14

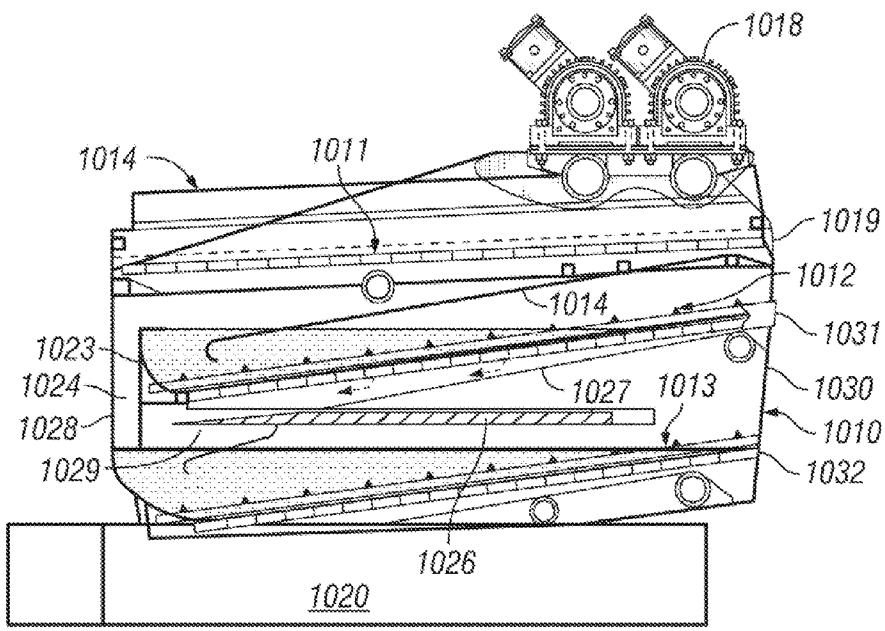

1018
1014
1011
1019
1012
1014
1031
1023
1027
1013
1030
1024
1028
1010
1029
1032
1026
1020

FIG. 15A

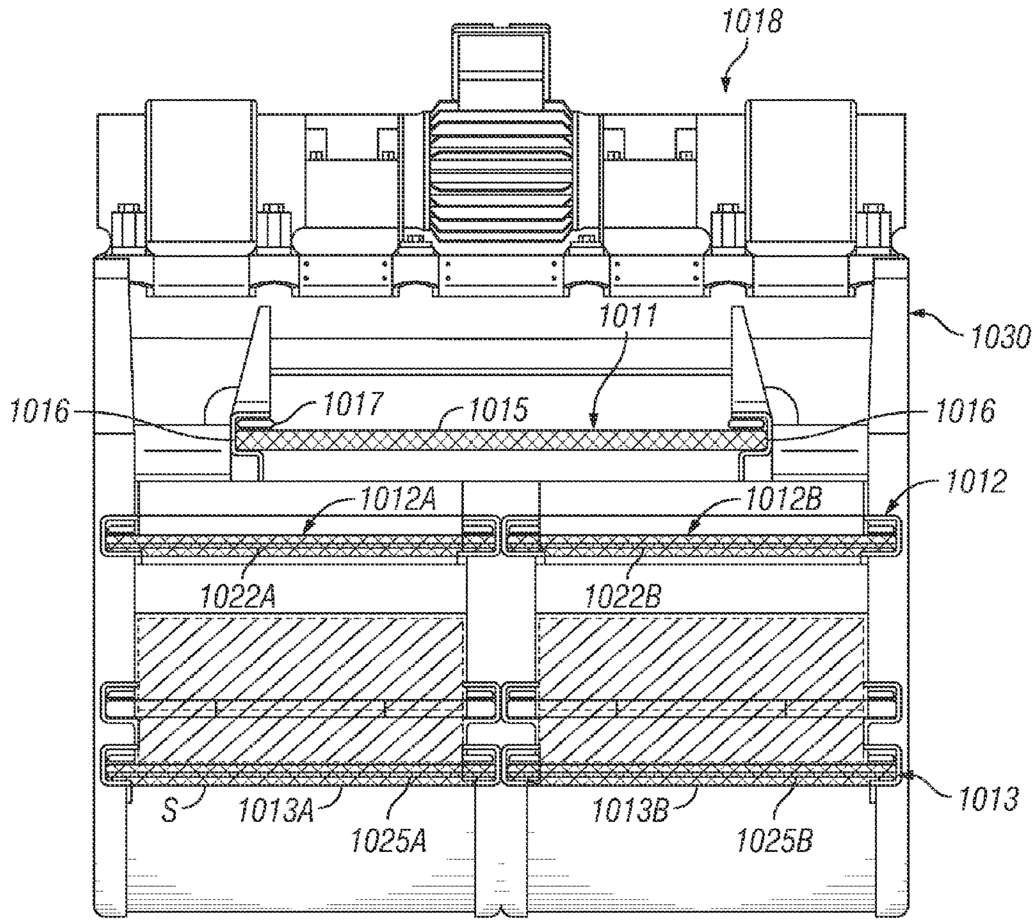

1018
1030
1011
1016
1017
1015
1016
1012
1012A
1012B
1022A
1022B
S
1013A
1025A
1013B
1025B
1013

FIG. 15B

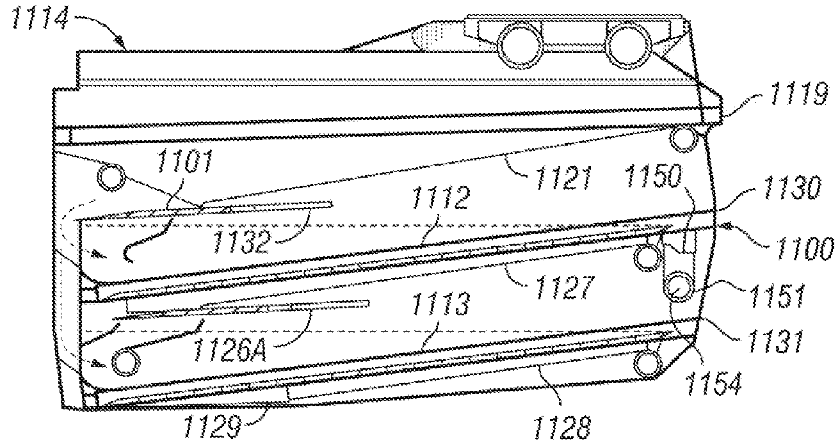


FIG. 16

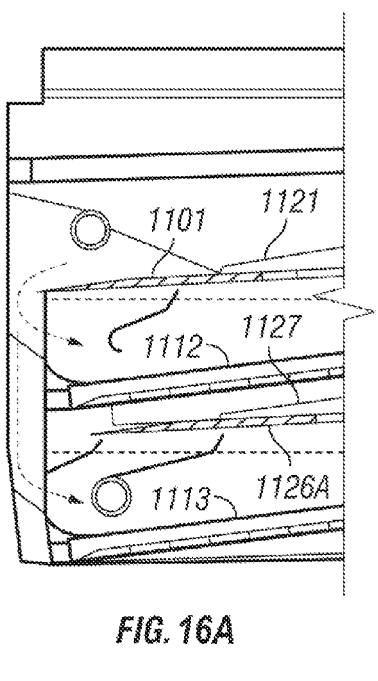


FIG. 16A

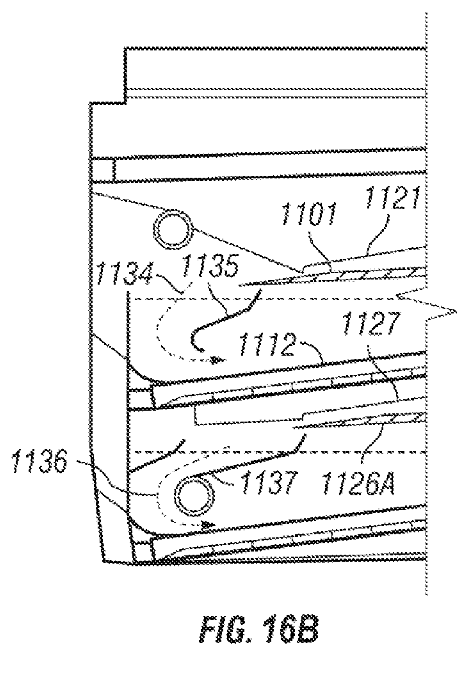


FIG. 16B

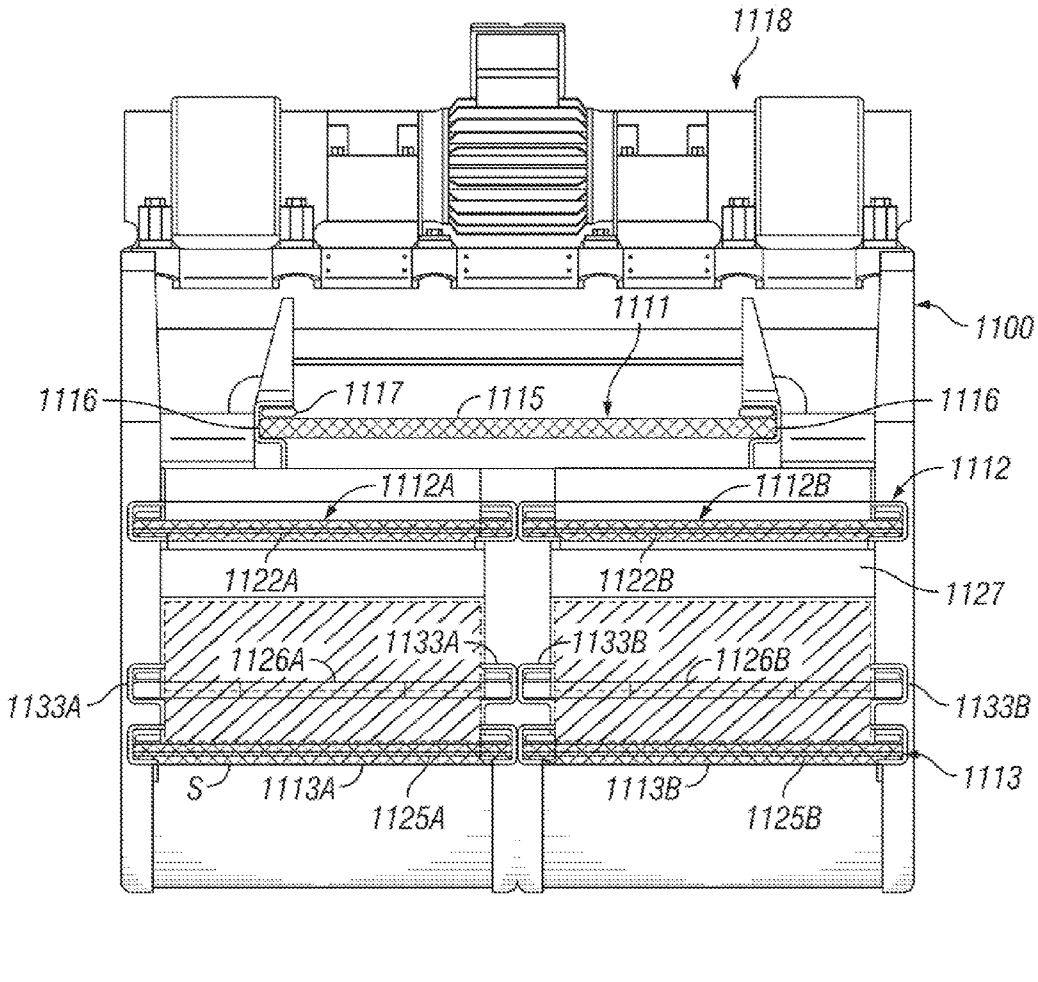

1118
1100
1111
1116
1117
1115
1116
1112A
1112B
1112
1122A
1122B
1127
1133A
1133B
1126A
1126B
1133A
1133B
1113
S
1113A
1125A
1113B
1125B

FIG. 16C

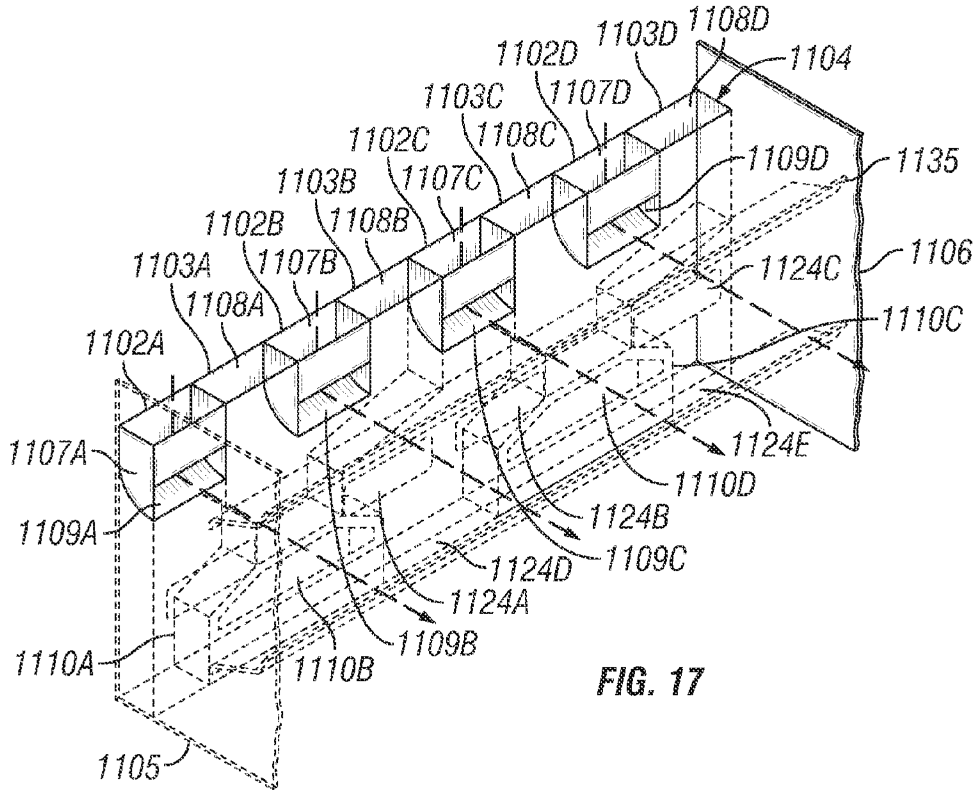

1102A
1103A
1108A
1102B
1107B
1103B
1108B
1102C
1107C
1103C
1108C
1102D
1107D
1103D
1108D
1104
1109D
1135
1106
1124C
1110C
1124E
1110D
1124B
1109C
1124D
1124A
1109B
1110B
1110A
1107A
1109A
1105

FIG. 17

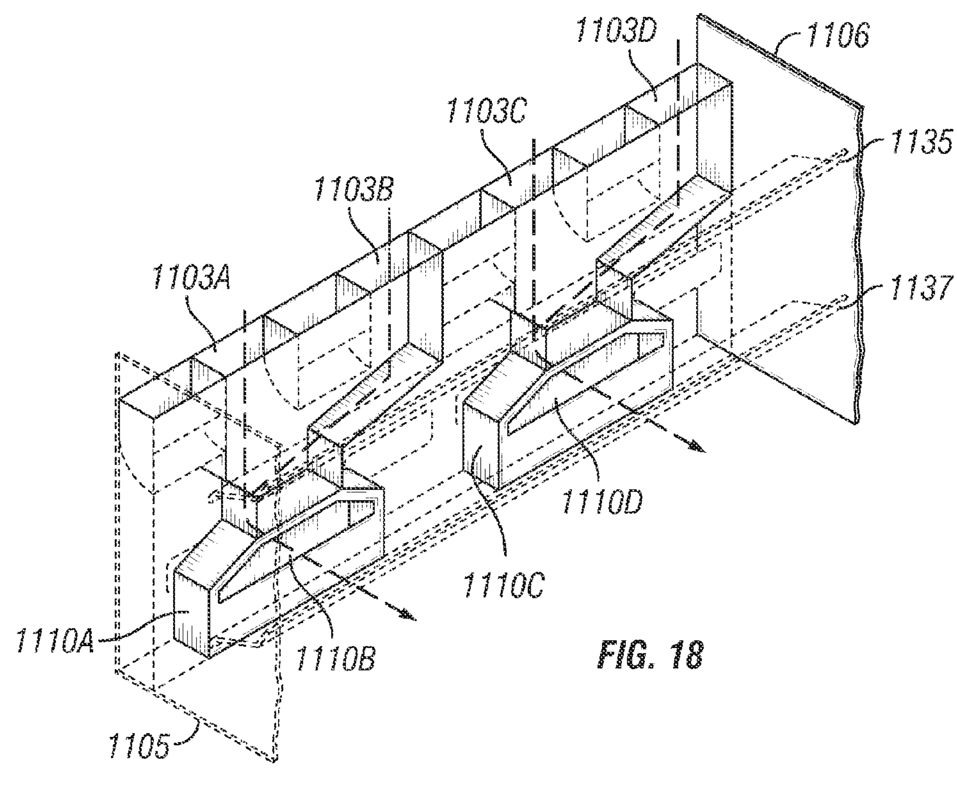

1103D
1106
1103C
1135
1103B
1103A
1137
1110D
1110C
1110A
1110B
1105

FIG. 18

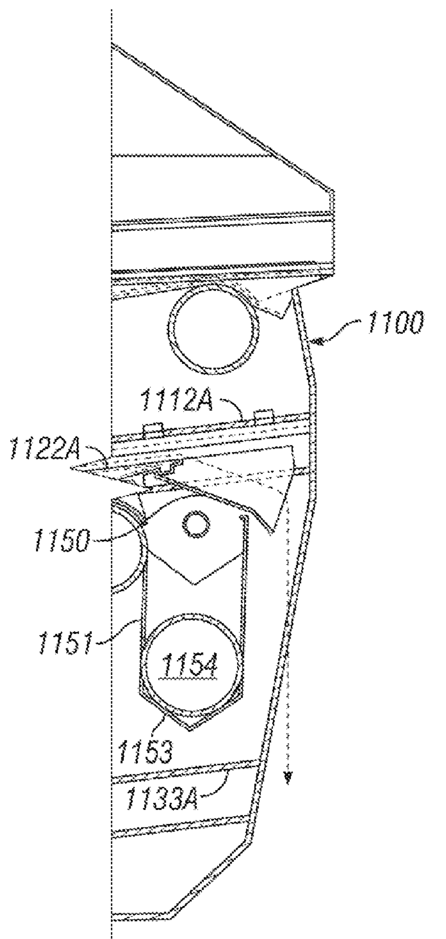


FIG. 19A

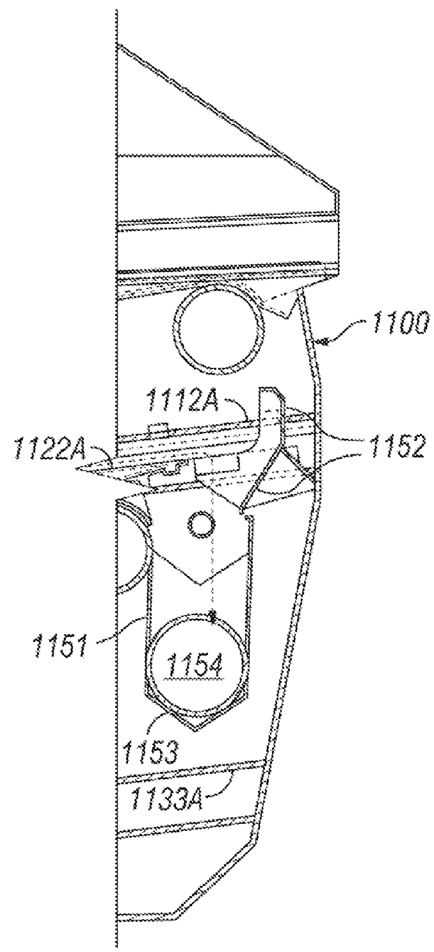


FIG. 19B

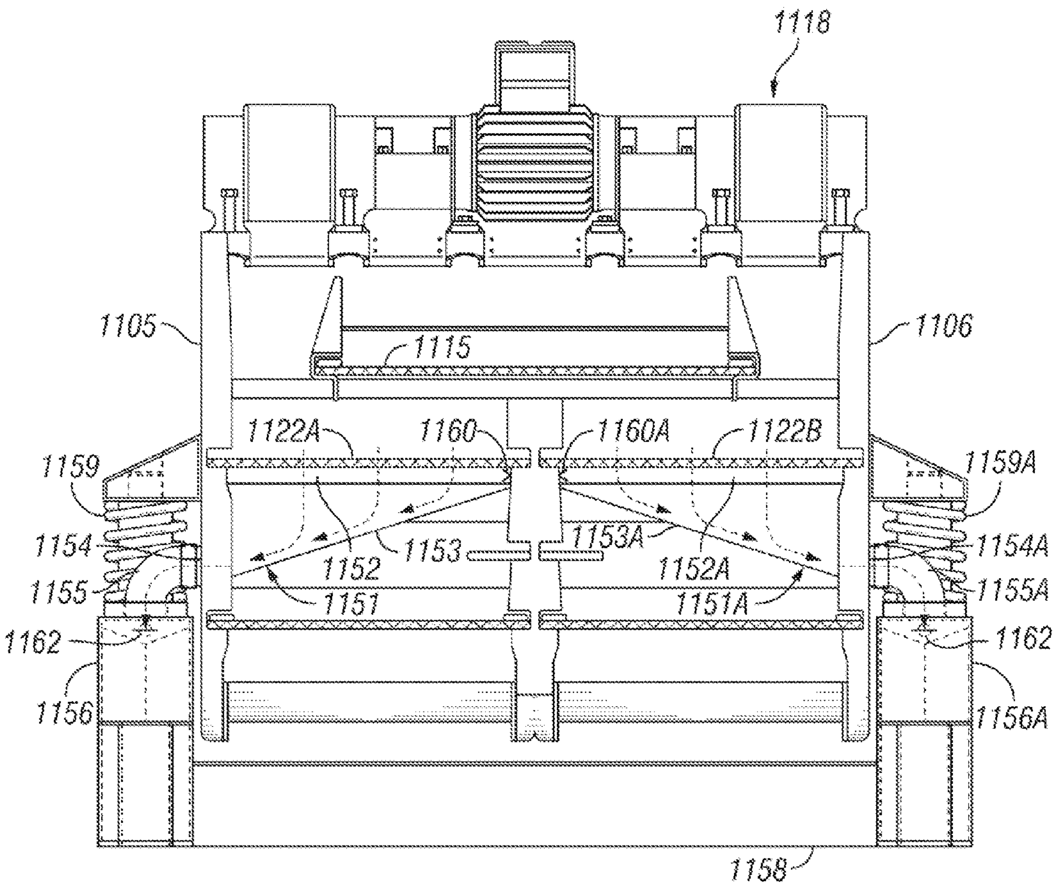

1118
1105
1106
1115
1122A
1160
1160A
1122B
1159
1159A
1154
1152
1153
1153A
1152A
1154A
1155
1151
1151A
1155A
1162
1162
1156
1156A
1158

FIG. 20

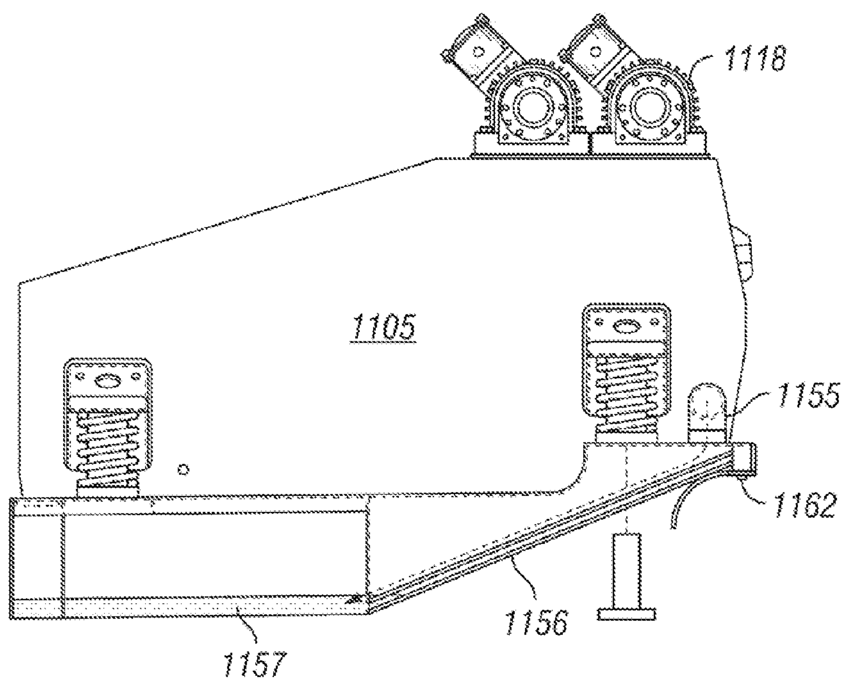


FIG. 21

SHALE SHAKER

CROSS-REFERENCE TO RELATED APPLICATIONS

This Application is a continuation-in-part of Ser. No. 12/490,492 filed on Jun. 24, 2009 now U.S. Pat. No. 8,556,083 entitled "Shale Shaker flow Diverter", which is a continuation-in-part of U.S. application Ser. No. 12/287,709 filed on Oct. 10, 2008 now U.S. Pat. No. 8,113,356 entitled "Systems and Methods For the Recovery of Lost Circulation and Similar Material" both of which are incorporated by reference herein for all they disclose.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention is directed to drilling fluid processing systems; shale shakers; to methods for using these things; and, in certain particular aspects, to shale shakers with structure for converting shaker fluid flow paths from series to parallel, and vice versa.

2. Description of the Related Art

In the oil and gas industries, shale shakers use screens to treat drilling fluid contaminated with undesirable solids. Typically such apparatuses have a basket, deck, or other screen holding or mounting structure mounted in or over a receiving receptacle or tank and vibrating apparatus for vibrating one or more screens. Material to be treated is introduced to the screen(s) either by flowing it directly onto the screen(s) or by flowing it into a container, tank, or "possum belly" from which it then flows to the screen(s). Often, the screen or screens used to treat material is sealed in place on a screen deck, in a screen basket, or on screen mounting structure.

In the drilling of a borehole in the construction of an oil or gas well, a drill bit is arranged on the end of a drill string, which is rotated to bore the borehole through a formation. A drilling fluid known as "drilling mud" is pumped through the drill string to the drill bit to lubricate the drill bit. The drilling mud is also used to carry the cuttings produced by the drill bit and other solids to the surface through an annulus formed between the drill string and the borehole. The density of the drilling mud is closely controlled to inhibit the borehole from collapse and to ensure that drilling is carried out optimally. The density of the drilling mud affects the rate of penetration of the drill bit. By adjusting the density of the drilling mud, the rate of penetration changes at the possible detriment of collapsing the borehole. The drilling mud may also carry lost circulation materials for sealing porous sections of the borehole. The acidity of the drilling mud may also be adjusted according to the type of formation strata being drilled through. The drilling mud contains inter alia expensive synthetic oil-based lubricants and it is normal therefore to recover and re-use the used drilling mud, but this requires inter alia the solids to be removed from the drilling mud. This is achieved by processing the drilling mud. The first part of the process is to separate the solids from the solids laden drilling mud. This is at least partly achieved with a vibratory separator, such as those shale shakers disclosed in U.S. Pat. No. 5,265,730, WO 96/33792 and WO 98/16328. Further processing equipment such as centrifuges and hydrocyclones may be used to further clean the mud of solids. The solids are covered in contaminates and residues. It is not uncommon to have 30 to 100 m3 of drilling fluid in circulation in a borehole.

The resultant solids, known herein as "drill cuttings" are processed to remove substantially all of the residues and

contaminates from the solids. The solids can then be disposed of in a landfill site or by dumping at sea in the environment from which the solids came. Alternatively, the solids may be used as a material in the construction industry or have other industrial uses.

Shale shakers generally comprise an open bottomed basket having one open discharge end and a solid walled feed end. A number of rectangular screens are arranged over the open bottom of the basket. The screens may be substantially planar or have a slight crown. The basket is arranged on springs above a receptor for receiving recovered drilling mud. A skip or ditch is provided beneath the open discharge end of the basket. A motor is fixed to the basket, which has a drive rotor provided with an offset clump weight. In use, the motor rotates the rotor and the offset clump weight, which causes the basket and the screens fixed thereto to shake. Solids laden mud is introduced at the feed end of the basket on to the screens. The shaking motion induces separation of the drilling mud from the solids, the drilling mud passing through the screens and the solids above the screens. The shaking motion also induces the solids to move along the screens towards the open discharge end. The recovered drilling mud is received in the receptor for further processing and the solids pass over the discharge end of the basket into the ditch or skip.

The rectangular screens may be arranged at an angle to horizontal, such as a seven degrees incline from the feed end to the discharge end of the shale shaker. The angle may be adjustable. The screens are generally fixed in the basket and the basket is adjustable to adjust the angle of the screens relative to horizontal. The flow of solids laden drilling fluid may form a pool on the inclined screens. The action of the vibratory mechanism induces solids to climb the inclined screens to the discharge end of the shaker and into the ditch or skip.

Generally, a vibratory mechanism inducing a circular vibration will tend to throw solids from the screen into the air in random directions. A vibratory mechanism inducing an elliptical motion will induce the solids to move in a direction of the longest chord of the ellipse. A shale shaker having a vibratory mechanism inducing a very thin ellipse is known as a linear shale shaker and induces fast movement of solids along the screen, although the screen tends to suffer fast degradation due to sudden deceleration of the solids as they meet the screen.

The screens are generally of one of two types: hook-strip; and pre-tensioned.

The hook-strip type of screen comprises several rectangular layers of mesh in a sandwich, usually comprising one or two layers of fine grade mesh and a supporting mesh having larger mesh holes and heavier gauge wire. The layers of mesh are joined at each side edge by a strip which is in the form of an elongate hook. In use, the elongate hook is hooked on to a tensioning device arranged along each side of a shale shaker. The shale shaker further comprises a crowned set of supporting members, which run along the length of the basket of the shaker, over which the layers of mesh are tensioned. An example of this type of screen is disclosed in GB-A-1,526,663. The supporting mesh may be provided with or replaced by a panel having apertures therein. The pre-tensioned type of screen comprises several rectangular layers of mesh, usually comprising one or two layers of fine grade mesh and a supporting mesh having larger mesh holes and heavier gauge wire. The layers of mesh are pre-tensioned on a rigid support comprising a rectangular angle iron frame and adhered thereto. The screen is then inserted into C-channel rails arranged in a basket of a shale shaker. An example of this type of screen is disclosed in GB-A-1,578,948 and an example of a shale shaker suitable for receiving the pre-tensioned type screens is disclosed in GB-A-2,176,424.

A problem associated with shale shakers is that screens used therein tend to blind, especially when the solids are gummy, such as clay, or of a size close to the size of the mesh size of the screen. The latter type of blinding is known as near-sized particle blinding. A number of solutions have been proposed to tackle this problem, such as disclosed in GB-A-1,526,663 in which a screen assembly using two layers of screening material in a sandwich and allowing the layers of screening material to move independently to dislodge any near sized particles lodged in one of the screens.

It is advantageous to use fine-meshed filters to filter very small particles, for example of a size in the range of 50-200μ or more, without the filtering device clogging up with the small particles. However, it is the fine-meshed filters in particular that are prone to such undesired clogging.

It is also advantageous to have a simple reliable separator to inhibit down-time for maintenance and repair.

It is preferable in certain circumstances to retain particles, for example of a particle size in the range of 50-60μ or larger, by means of a filter.

In the past it has been common to use multiple screens at multiple levels in a shale shaker to process drilling fluid, e.g., screens at one, two or three levels. "Lost circulation" of drilling fluid occurs when, in drilling a wellbore, the circulation of drilling fluid to and then away from the drill bit ceases due to the porosity of the formation and/or due to fracturing of the formation through which the wellbore is being drilled. When lost circulation occurs, drilling fluid is pumped into the fractured formation rather than being returned to the surface. Often circulation is lost at some specific depth where the formation is "weak", and that the fracture extends horizontally away from the borehole. Expressions used to describe rocks that are susceptible to lost returns include terms like vugular limestone, unconsolidated sand, "rotten" shale, and the like.

A wide variety of "lost circulation materials" ("LCM") have been pumped into wellbores to fill or seal off a porous formation or to fill or seal off a wellbore fracture so that a proper route for drilling fluid circulation is re-established. Often lost circulation materials are generally divided into fibres, flakes, granules, and mixtures. Often it is also desirable to recover and retain the lost circulation material in the drilling mud system during continuous circulation. Screening the drilling mud for removal of undesired particulate matter can also result in removal of the lost circulation material and, therefore, require continuous introduction of new lost circulation material to the drilling mud downstream of the mud screening operation. The addition of lost circulation material compounds the separating problems because it, like the drilling fluid, is preferably cleaned and recirculated. Exiting the well is the drilling fluid of small size, the lost circulation material of a large size, and the undesirable material of a size there-between, with the largest and smallest of the materials, and/or materials larger than the lost circulation material, to be re-circulated.

One proposed solution to this separation problem is a conventional two step screening process as shown in U.S. Pat. No. 4,116,288. There the exiting mixture of drilling fluid, lost circulation material and undesirable material is first subjected to a coarse screening to separate the lost circulation material from the drilling fluid and undesirable material which drops to a second finer screen there-below to separate the drilling fluid from the undesirable material. The drilling fluid and lost circulation material are then reunited for recirculation into the well. This system is susceptible to height restrictions and fine screen problems. The lost circulation material can be coated with undesirable material which will not go through a first screen, moves over and exits off of the top side of the first screen, and is circulated back into a well.

There are a variety of known drilling fluid processing systems, shale shakers, and methods for recovery of lost circulation material; including, for example, but not limited to, those in U.S. Pat. Nos. 6,868,972; 6,669,027; 6,662,952; 6,352,159; 6,510,947; 5,861,362; 5,392,925; 5,229,018; 4,696,353; 4,459,207; 4,495,065; 4,446,022; 4,306,974; 4,319,991; and 4,116,288 (all said patents incorporated by reference herein for all purposes).

In certain prior systems, problems have been encountered with systems for screening out lost circulation material when undesirable material of the same size is also screened out.

In the drilling of an oil or gas well, cracks may exist in the wall of the wellbore. Such cracks in the formation may propagate, which could cause structural problems in the wall of the wellbore and/or allow drilling fluids to escape therethorough into the formation. Furthermore, if substantial amounts of drilling fluids are lost, the pressure in the drilling fluid in the wellbore may drop, which could cause collapse of the wellbore. Accordingly, Wellbore Strengthening Materials may be added to circulated drilling fluid. The Wellbore Strengthening Materials comprise sized particles. When the drilling fluid is circulated around the wellbore wall with cracks therein, the sized particles wedge themselves in the cracks, which reduces the likelihood of the cracks propagating. It is beneficial to recover these sized particles and reuse them in circulated drilling mud. Shale shakers have thus been modified to size solids in solids laden drilling fluid. Such a shale shaker is disclosed in U.S. Ser. No. 12/490,492. A range of sizes of solids can be extracted using such a shale shaker and re-circulated as Wellbore Strengthening Material in fresh drilling fluid.

It is preferable to remove fine solids from the solids laden drilling fluid. These fine solids can be very invasive and increase rates of wear in parts that make up the well bore and the drill string.

BRIEF SUMMARY OF THE INVENTION

The present invention discloses, in certain aspects, According to the present invention, there is provided a shale shaker for separating solids from solids laden drilling fluid, the shale shaker comprising a basket having at least one first screen deck and at least one second screen deck and at least one first duct and at least one second duct, wherein the basket further comprises a flow tray having at least one first duct opening for the at least one first duct and at least one second duct opening for the at least one second duct, the at least one first duct for directing solids laden drilling fluid to the at least one first screen deck and the at least one second duct for directing solids laden drilling fluid to the at least one second screen deck.

Preferably, the solids laden drilling fluid flows along the flow tray in a flow direction the flow tray having a flow tray width substantially transverse to the flow direction, the at least one first duct opening arranged across a first portion of the flow tray width and the second duct opening arranged across a second portion of the flow tray width, the first portion not overlapping the second portion.

Advantageously, the at least one first duct opening is a plurality of first duct openings, and the at least second duct opening is a plurality of second duct openings. Preferably, the solids laden drilling fluid flows along the flow tray in a flow direction, the plurality of first duct openings interleaved with the plurality of second duct openings, the plurality of first and second duct openings arranged substantially perpendicularly to the flow direction.

Advantageously, the flow tray has a feed end and a discharge end, the first and second duct openings arranged at the discharge end of the flow tray. Preferably, the flow tray has a floor and at least one of the first and second duct openings is planar with the floor of the flow tray. Advantageously, the other of the first and second ducts has a duct opening planar with a floor of the flow tray. The solids laden drilling fluid thus does not pass over a weir and the solids laden drilling fluid is split across the first and second screen decks with an even consistency. An overflow from a weir tends to contain more fluid and low density solids and the fluid left in behind the weir tends to contain high density solids, which tend to be sharp and aggressive which wear screening material out quickly. It is advantageous for the screen assemblies to wear evenly, so that all screens can be changed at one time, which reduces downtime of the shale shaker. Preferably, the duct opening is in the form of a planar opening a floor of the flow tray. Advantageously, the duct opening is perpendicular to the floor of the flow tray, the duct opening defined by a perimeter. Preferably, at least a portion of the perimeter is planar with the floor of the flow tray, so that all of the solids laden drilling fluid passes through the duct openings and noen gets trapped on the flow tray. Advantageously, the flow tray further comprises a valve for directing the solids laden drilling fluid to one of the at least one first screen deck and the at least first and second duct openings. Preferably, the flow tray has at least one gate opening therein and the valve is a gate valve comprising a gate tray slide-able from closed position closing off the gate opening to a position closing the gate opening.

Preferably, the shale shaker further comprises a scalping screen for removing large solids from the solids laden drilling fluid, the solids laden drilling fluid flowing therefrom on to the flow tray and the large solids passing over the scalping screen. Advantageously, the large solids pass over the scalping screen into one of a: skip; and ditch. Preferably, the ditch comprises an auger which moves the solids into a hopper of a solids conveying apparatus, such a positive pressure pneumatic conveying apparatus. Preferably, the at least one first screen deck has a screened fluid flow tray thereunder for collecting and guiding the screened drilling fluid. Advantageously, the at least one second screen deck has a screened fluid flow tray thereunder for collecting and guiding the screened drilling fluid. Preferably, the basket further comprises at least one discharge duct for directing the screened drilling fluid from the screened fluid flow tray to a sump arranged beneath the basket.

Preferably, the at least one first screen deck is an upper screen deck and the at least one second screen deck is a lower screen deck, the lower screen deck at least part of which is arranged beneath the upper screen deck. Advantageously, the at least one first screen deck is an upper screen deck and the at least one second screen deck is a lower screen deck, the lower screen deck wholly arranged beneath the upper screen deck.

Preferably, the basket further comprises a trough, wherein the at least one first screen deck has a solids discharge end and the trough is arranged thereunder to receive solids. Preferably the trough is made from a composite material, although it may be made from a sheet steel or other metal or plastics material. Preferably, the shale shaker further comprises a sump arranged below the basket, the tough arranged to feed solids into the sump. Advantageously, the basket further comprising a jetting nozzle arranged to jet screened drilling fluid into the trough to facilitate flow of solids therethrough.

Preferably, the basket further comprises a flexible duct, solids flowing through the trough into the flexible duct and into the sump. The flexible duct preferably leads from a side wall of the basket to a sump arranged therebelow, the flexible duct allowing the basket to isolate the basket from the base to inhibit vibrations passing to the base.

Preferably, the basket further comprises a trough and a diverter plate, wherein the at least one first screen deck has a solids discharge end and the trough is arranged thereunder, the diverter plate to guide solids into the trough. Advantageously, the basket further comprises a trough and a diverter cap, wherein the at least one first screen deck has a solids discharge end and the trough is arranged thereunder, the diverter cap to inhibit solids flowing into the trough. Preferably, the shale shaker further comprises one of a skip and ditch, wherein the diverter cap guides solids into the one of the skip and the ditch.

Preferably, the at least one first screen deck comprises a left-hand first screen deck and a right-hand first screen deck. Advantageously, the at least one second screen deck comprises a left-hand and a right-hand screen deck.

Advantageously, the basket has a feed end and a solids discharge end, the at least one first screen deck arranged at an uphill angle from horizontal from the feed end of the basket to the solids discharge end. Preferably, the first and second screen decks are arranged at an uphill angle of between three and twelve degrees and most preferably seven degrees. Advantageously, the basket angle can be adjusted to alter the angle of the at least one first and second screen decks. Alternatively, the at least one first and second screen decks are arranged to be horizontal.

Preferably, the shale shaker further comprises at least one first screen assembly in the at least one first screen deck and at least one second screen assembly in the second screen deck. Advantageously, the first screen assembly has screening material thereon and the second screen assembly has screening material thereon, wherein the screening material of the first screen assembly is the same as the screening material of the second screen assembly to provide the same cut point. The shale shaker is most likely to be operating in parallel mode with this arrangement. Parallel mode tends to be used when large volumes of drilling fluid are required in a drilling operation, such as when boring a large diameter hole, which normally occurs when drilling the top first portion of the well.

Alternatively, the first screen assembly has screening material thereon and the second screen assembly has screening material thereon, wherein the screening material of the second screen assembly is finer than the screening material of the first screen assembly to provide the different cut points. The shale shaker is most likely to be operating in series mode with this arrangement.

Preferably, the shale shaker further comprises a fixed base, the basket suspended from the base on at least one spring, the basket further comprising a vibrating apparatus for vibrating the basket and the at least one first and second screen decks arranged therein. The present invention also provides a method for separating solids from solids laden drilling fluid using a shale shaker comprising a basket having a flow tray with at least first and second duct openings, at least first and second ducts, at least one first screen deck and at least one second screen deck, the method comprising the steps of flowing solids laden drilling fluid over the flow tray, through the at least first and second duct openings into the at least first and second ducts, the at least one first duct directing solids laden drilling fluid to the at least one first screen deck and the at least one second duct directing solids laden drilling fluid to the second screen deck.

The present invention also provides a shale shaker for separating solids from solids laden drilling fluid, the shale shaker comprising a basket having a scalping screen deck, at least one first screen deck and at least one second screen deck, wherein the basket further comprises a flow tray arranged between the scalping screen deck and the at least one first screen deck, and a plurality of first ducts and a plurality of second ducts, the plurality of first ducts for directing solids laden drilling fluid to the at least one first screen deck and the second plurality of second ducts for directing solids laden drilling fluid to the second screen deck.

Preferably, the flow tray has at least one gate opening therein and a gate valve comprising a gate tray slideable from a closed position closing off the gate opening to an open position opening the gate opening allowing solids laden drilling mud to flow therethrough. Preferably, the gate opening is arranged upstream of the plurality of first and second ducts, such that no or only a little solids laden drilling fluid would reach the plurality of first and second ducts.

Advantageously, the basket further comprises a screened fluid flow tray arranged under the at least one first screen deck, the screened fluid flow tray having a selector opening therein and a selector gate valve for selectively opening and closing the selector opening to selectively allow screened drilling fluid to flow therethrough on to the at least one second screen deck.

The present invention also provides a shale shaker for separating solids from solids laden drilling fluid, the shale shaker comprising a base, a basket isolated from the base, the basket comprising a scalping deck, at least one first deck and at least one second deck, the at least one first deck having a feed end and a solids discharge end, a trough arranged in the basket at the discharge end of the at least one first deck and a diverter plate for selectively inhibiting and allowing solids discharged from the discharge end of the at least one first deck into the trough.

Preferably, the shale shaker further comprises a flexible duct leading from the trough into a sump arranged beneath the basket for collecting screened drilling fluid.

The present invention also provides a method for separating solids laden drilling fluid with a shale shaker, the shale shaker comprising a base, a basket isolated from the base, the basket comprising a scalping deck having a scalping screen, at least one first deck having a screen assembly and at least one second deck having a fine screen screen assembly, the at least one first deck having a feed end and a solids discharge end, a trough arranged in the basket at the discharge end of the at least one first deck and a diverter plate the method comprising the steps of flowing solids laden drilling mud on to the scalping screen large solids passing over the scalping screen and solids laden drilling fluid passing through the scalping deck to the screen assembly of the at least one first screen deck sized solids passing over the screen assembly into the trough guided by the diverter plate into the trough.

Preferably, the method further comprises the step of flowing the sized solids from the trough into a sump under the basket, the sump also collecting screened drilling fluid screened by the fine mesh screens of the at least one second screen deck. Advantageously, flowing of the sized solids is facilitated by a jet of drilling fluid. The present invention discloses, in certain aspects, methods and systems for processing drilling fluid to recover components thereof and, in one particular aspect to multiBurnett, screen shale shakers in which fluid flow paths can be selectively changed from series to parallel, and vice versa.

In certain particular aspects, such methods and systems employs a novel shale shaker according to the present invention with screening apparatus including multiple screens and conversion apparatus for changing a first separation mode from material flowing from one screen to another in series to a second separation made in which fluid flows to multiple screens in parallel.

The present invention discloses, in certain aspects, a system for processing a mixture of drilling fluid and solid material to separate at least one component of the mixture by size from the mixture, the system including: a vibratable basket for receiving an input flow of drilling fluid with solids therein; a plurality of spaced-apart screen assemblies including a first screen assembly and a second screen assembly positioned below the first screen assembly; the screen assemblies mounted in the vibratable basket and vibratable therewith; conversion apparatus associated with the screen assemblies for selectively controlling the input flow to select one of series flow and parallel flow to the screen assemblies; drilling fluid flowable through the first screen assembly; and drilling fluid flowable through the second screen assembly and flowable down therefrom.

A vibratory separator or shale shaker, in one embodiment according to the present invention has a screen or screens at separate levels as described herein according to the present invention. In one particular aspect, two lowermost screens receive flow from a higher screen. Conversion apparatus permits this flow to be selectively changed from parallel to series, or vice-versa. The present invention, in certain embodiments, includes a vibratory separator or shale shaker with a base or frame; a "basket" or screen mounting apparatus on or in the base or frame; multiple screens at different, spaced apart distinct levels according to the present invention; vibrating apparatus; mode conversion apparatus; and a collection tank or receptacle. Such a shale shaker can treat drilling fluid with solids therein, e.g. cuttings, debris, etc.; and drilling fluid with lost circulation material therein.

The present invention discloses, in certain aspects, a conversion apparatus for a system for processing a mixture of drilling fluid and solid material to separate at least one component of the mixture from the mixture, the system including a vibratable basket for receiving an input flow of drilling fluid with solids therein, a plurality of spaced apart screen assemblies including a first screen assembly and a second screen assembly positioned below the first screen assembly, the screen assemblies mounted in the vibratable basket and vibratable therewith, drilling fluid flowable through the first screen assembly and the second screen assembly down therefrom, the conversion apparatus associated with the screen assemblies for selectively controlling the input flow to select one of series flow and parallel flow, the conversion apparatus including: a body, a first flow channel through the body for effecting system parallel flow to the screen assemblies, and a second flow channel through the body for effecting system series flow to the screen assemblies.

In certain particular aspects, an insert between screens is a movable gate structure between screens provides the mode conversion feature. In other aspects inserts adjacent screens, appropriate flow channelling, and appropriately located flowback barriers provide this mode conversion feature.

The present invention discloses, in certain aspects, a method for treating a flow of drilling fluid with solids, the method including introducing the flow of drilling fluid with solids to a system for separating at least one component from the flow, the system as any herein according to the present invention, the method further including selecting one of a system series flow to the screen assemblies or a system parallel flow to the screen assemblies using a conversion apparatus, flowing drilling fluid with solids to the screen assemblies, and screening the flow to each screening assembly.

The present invention discloses, in certain aspects, methods and systems for processing drilling fluid to recover components thereof and, in one particular aspect for separating lost circulation material (or lost circulation material along with solids of similar size) from used drilling fluid. In certain aspects, the separated lost circulation material is recovered and used.

In certain particular aspects, such methods and systems employs a novel shale shaker according to the present invention with screening apparatus below an initial scalper screen apparatus for separating lost circulation material (and/or material of similar size) from used drilling fluid.

A vibratory separator or shale shaker, in one embodiment according to the present invention has a screen or screens at separate levels as described herein according to the present invention. In one particular aspect, two lowermost screens can receive flow from a higher screen in parallel or in series. The present invention, in certain embodiments, includes a vibratory separator or shale shaker with a base or frame; a "basket" or screen mounting apparatus on or in the base or frame; screens at three or four different, spaced-apart distinct levels according to the present invention; vibrating apparatus; and a collection tank or receptacle. Such a shale shaker can treat drilling fluid contaminated with solids, e.g. cuttings, debris, etc.; and drilling fluid with lost circulation material (and/or material of similar size) therein. Such a shale shaker, in certain aspects, provides a separate exit stream from a second screening level which is primarily lost circulation material (and/or material of similar size).

Accordingly, the present invention includes features and advantages which are believed to enable it to advance the processing of drilling fluid with lost circulation material (and/or material of similar size) therein. Characteristics and advantages of the present invention described above and additional features and benefits will be readily apparent to those skilled in the art upon consideration of the following detailed description of preferred embodiments and referring to the accompanying drawings.

Certain embodiments of this invention are not limited to any particular individual feature disclosed here, but include combinations of them distinguished from the prior art in their structures, functions, and/or results achieved. Features of the invention have been broadly described so that the detailed descriptions that follow may be better understood, and in order that the contributions of this invention to the arts may be better appreciated. There are, of course, additional aspects of the invention described below and which may be included in the subject matter of the claims to this invention. Those skilled in the art who have the benefit of this invention, its teachings, and suggestions will appreciate that the conceptions of this disclosure may be used as a creative basis for designing other structures, methods and systems for carrying out and practicing the present invention. The claims of this invention are to be read to include any legally equivalent devices or methods which do not depart from the spirit and scope of the present invention.

In addition to the specific objects stated below for at least certain preferred embodiments of the invention, other objects and purposes will be readily apparent to one of skill in this art who has the benefit of this invention's teachings and disclosures. It is, therefore, an object of at least certain preferred embodiments of the present invention to provide the embodiments and aspects listed above and: New, useful, unique, efficient, non-obvious drilling fluid processing systems; shale shakers; and methods of the use of these systems and shakers;

Such shale shakers with screens at multiple levels and mode conversion apparatus so that material is screenable by multiple screens in series or in parallel selectively as desired; Such shale shakers with screens at four levels according to the present invention with the last two screens operating in series or in parallel; and new, useful, unique, efficient, non-obvious drilling fluid processing systems and shale shakers; and methods of their use for separating and recovering lost circulation material (and/or material of similar size) from spent drilling fluid. The present invention recognizes and addresses the problems and needs in this area and provides a solution to those problems and a satisfactory meeting of those needs in its various possible embodiments and equivalents thereof. To one of skill in this art who has the benefits of this invention's realizations, teachings, disclosures, and suggestions, other purposes and advantages will be appreciated from the following description of certain preferred embodiments, given for the purpose of disclosure, when taken in conjunction with the accompanying drawings. The detail in these descriptions is not intended to thwart this patent's object to claim this invention no matter how others may later attempt to disguise it by variations in form, changes, or additions of further improvements. The Abstract that is part hereof is neither intended to define the invention, which is done by the claims, nor is it intended to be limiting of the scope of the invention or of the claims in any way.

It will be understood that the various embodiments of the present invention may include one, some, or all of the disclosed, described, and/or enumerated improvements and/or technical advantages and/or elements in claims to this invention. Certain aspects, certain embodiments, and certain preferable features of the invention are set out herein. Any combination of aspects or features shown in any aspect or embodiment can be used except where such aspects or features are mutually exclusive.

BRIEF DESCRIPTION OF THE DRAWINGS

A more particular description of embodiments of the invention briefly summarized above may be had by references to the embodiments which are shown in the drawings which form a part of this specification. These drawings illustrate certain preferred embodiments and are not to be used to improperly limit the scope of the invention which may have other equally effective or legally equivalent embodiments.

FIG. **1** is a schematic view of a system according to the present invention.

FIG. **1**A is a perspective view of a shale shaker according to the present invention.

FIG. **2**A is a side view, partially in cross-section, of a shale shaker according to the present invention.

FIG. **2**B is a cross-sectional view of the screens and related structure of the shale shaker of FIG. **2**A.

FIG. **2**C is a cross-sectional view of a shale shaker according to the present invention.

FIG. **3**A is a side cutaway view of a shale shaker according to the present invention.

FIG. **3**B is a side cutaway view of a shale shaker according to the present invention.

FIG. **4**A is a perspective exploded view of a system according to the present invention.

FIG. **4**B is a schematic side view of the system of FIG. **4**A.

FIG. **5**A' is a perspective exploded view of a system according to the present invention.

FIG. **5**A" is a continuation of FIG. **5**A'.

FIG. **5**B is a schematic side view of the system of FIG. **5**A.

FIG. 6A is a side cross-sectional view of a shale shaker according to the present invention.

FIG. 6B is a side cross-sectional view of the shale shaker of FIG. 6A.

FIG. 6C is a side cross-sectional view of a shale shaker according to the present invention.

FIG. 6D is a side cross-sectional view of the shale shaker of FIG. 6C.

FIG. 6E is a perspective view of a diverter according to the present invention.

FIG. 6F is a front view of the shaker of FIG. 6A.

FIG. 6G is a cross-section view of the diverter of FIG. 6E in the shaker of FIG. 6A.

FIG. 7A is a side cross-sectional view of a shale shaker according to the present invention.

FIG. 7B is a side cross-sectional view of a shale shaker according to the present invention.

FIG. 7C is a perspective view of a flow barrier according to the present invention.

FIG. 7D is a perspective view of a flow barrier according to the present invention.

FIG. 8A is a side cross-sectional view of a shale shaker according to the present invention.

FIG. 8B is a side cross-sectional view of a shale shaker according to the present invention.

FIG. 8C is a perspective view of an insert according to the present invention.

FIG. 8D is a perspective view of a channel apparatus according to the present invention.

FIG. 8E is a perspective view of an insert according to the present invention.

FIG. 9A is a side cross-sectional view of a shale shaker according to the present invention.

FIG. 9B is a side cross-sectional view of the shale shaker of FIG. 9A.

FIG. 9C is a side cross-sectional view of a shale shaker according to the present invention.

FIG. 9D is a side cross-sectional view of the shale shaker of FIG. 9C.

FIG. 9E is a perspective view of an insert according to the present invention.

FIG. 9F is a top view of the insert of FIG. 9E.

FIG. 9G is a is a perspective view of another insert according to the present invention.

FIG. 9H is a is a top view of the insert of FIG. 9G.

FIG. 10A is a side cross-sectional view of a shale shaker according to the present invention.

FIG. 10B is a side cross-sectional view of a shale shaker according to the present invention.

FIG. 10C is a perspective view of an insert according to the present invention.

FIG. 10D is a top view of the insert of FIG. 10C.

FIG. 10E is a perspective view of a channel apparatus according to the present invention.

FIG. 10F is a perspective view of an insert according to the present invention.

FIG. 10G is a perspective view of an insert according to the present invention.

FIG. 11A is a side cross-sectional view of a shale shaker according to the present invention.

FIG. 11B is a side cross-sectional view of a shale shaker according to the present invention.

FIG. 11C is a top view of an insert according to the present invention.

FIG. 11D is a top view of an insert according to the present invention.

FIG. 11E is a top view of an insert according to the present invention.

FIG. 12A is a side cross-sectional view of a shale shaker according to the present invention.

FIG. 12B is a side cross-sectional view of the shale shaker of FIG. 12A.

FIG. 12C is a side cross-sectional view of a shale shaker according to the present invention.

FIG. 12D is a side cross-sectional view of the shale shaker of FIG. 12C.

FIG. 12E is a perspective view of an insert according to the present invention.

FIG. 12F is a top view of the insert of FIG. 12E.

FIG. 12G is another perspective view of the insert of FIG. 12E when viewed from an opposite side of the insert.

FIG. 13A is a side cross-sectional view of a shale shaker according to the present invention.

FIG. 13B is a side cross-sectional view of the shale shaker of FIG. 13A.

FIG. 13C is a side cross-sectional view of a shale shaker according to the present invention.

FIG. 13D is a side cross-sectional view of the shale shaker of FIG. 13C.

FIG. 13E is a perspective view of an insert according to the present invention.

FIG. 14 shows a perspective view of an apparatus for separating solids from solids laden drilling mud.

FIG. 15A is a side cross-sectional schematic view of an apparatus for separating and sizing solids from solids laden drilling mud, the apparatus comprising a base and a basket.

FIG. 15B is an end view of the basket shown in FIG. 15A with screen assemblies therein.

FIG. 16 is a side view in section of a basket of a shale shaker in accordance with the present invention.

FIG. 16A is an enlarged view of part of the basket shown in FIG. 16, with parts in a first mode of operation.

FIG. 16B is an enlarged view of part of the basket shown in FIG. 16 with parts in a second mode of operation.

FIG. 16C is an end view of the basket shown in FIG. 16 with screen assemblies therein.

FIG. 17 is a perspective view of a part of the basket shown in FIG. 16A with hidden parts shown, in the first mode of operation indicating direction of flow of solids laden drilling mud to an upper primary screen deck.

FIG. 18 is a perspective view of a part of the basket shown in FIG. 16A, with hidden parts shown, in the first mode of operation indicating direction of flow of solids laden drilling mud to a lower primary screen deck.

FIG. 19A is an enlarged view in cross section of a solids diverter apparatus of the basket shown in FIG. 3, in the first mode of operation.

FIG. 19B is an enlarged view of a solids diverter apparatus of the basket shown in FIG. 16, in the second mode of operation.

FIG. 20 is an end view in section of a shale shaker comprising the basket shown in FIG. 16, showing details of a solids diverter apparatus.

FIG. 21 is a side view of the shale shaker shown in FIG. 20 arranged over a sump, with some hidden parts shown.

Presently preferred embodiments of the invention are shown in the above-identified figures and described in detail below. Various aspects and features of embodiments of the invention are described below and some are set out in the dependent claims. Any combination of aspects and/or features described below or shown in the dependent claims can be used except where such aspects and/or features are mutually exclusive.

It should be understood that the appended drawings and description herein are of preferred embodiments and are not intended to limit the invention or the appended claims. On the contrary, the intention is to cover all modifications, equivalents and alternatives falling within the spirit and scope of the invention as defined by the appended claims. In showing and describing the preferred embodiments, like or identical reference numerals are used to identify common or similar elements. The figures are not necessarily to scale and certain features and certain views of the figures may be shown exaggerated in scale or in schematic in the interest of clarity and conciseness.

As used herein and throughout all the various portions (and headings) of this patent, the terms "invention", "present invention" and variations thereof mean one or more embodiment, and are not intended to mean the claimed invention of any particular appended claim(s) or all of the appended claims. Accordingly, the subject or topic of each such reference is not automatically or necessarily part of, or required by, any particular claim(s) merely because of such reference. So long as they are not mutually exclusive or contradictory any aspect or feature or combination of aspects or features of any embodiment disclosed herein may be used in any other embodiment disclosed herein.

DETAILED DESCRIPTION OF THE INVENTION

FIG. **1** illustrates a system S according to the present invention which includes a derrick **1** that extends vertically over a wellbore **2**. A tubular work string **3** extends into the wellbore **2**, and extends from the earth's surface to a desired depth within the wellbore. A flow line **4***a* is connected to the tubular work string **3**. A flow line **4***b* is connected to annular space **5** formed between the outer surface of tubular work string **3** and the inner surface of wellbore **2**. Drilling fluid (or "mud") for the system in a mud pit **6** is circulated through the overall mud system via a mud pump **7**. During typical drilling operations, fluid is pumped into the tubular work string **3** by the mud pump **7** through the flow line **4***a*, circulated out a bottom end **3***a* of the tubular work string **3** (e.g., but not limited to, out from a drill bit **9**), up an annulus **5** of the wellbore **2**, and out of the annulus **5** via the flow line **4***b*.

Spent (or used) fluid mud exiting the wellbore annulus **5** through the flow line **4***b* includes drilling fluid, drill cuttings, lost circulation material (and/or material of similar size), and other debris encountered in the wellbore **2**. Accordingly, the spent drill cuttings mixture leaving the well is directed to a separation device, such as one or more shale shakers **8** according to the present invention. The combined mixture of drilling fluid, added material (e.g. solids and/or lost circulation material, etc.), debris, and drilled cuttings are directed to the shale shakers **8**. Liquid drilling fluid passes through screens at the same or at different levels of the shaker, e.g. screens **8***a*, **8***b*, **8***c*, **8***d* which are at four different levels of the shale shakers **8** and is directed into the mud pit **6** (or the two lowermost screens are at the same level each receiving a portion of flow from the screen **8***b*). Drill cuttings and other solids pass over the screens **8***a*-**8***d* of the shale shakers **8** and are discharged (arrows **8***e*, **8***f*, **8***g*, **8***h*). With the proper selection of screen mesh for the screen **8***b*, lost circulation material (with some material of similar size, if present) is separated by and discharged from the top of the screen **8***b* (see arrow **8***f*). The recovered lost circulation material (and/or material of similar size) flows and/or is pumped to a mud pit, a reservoir, or to a further processing apparatus **8***k*. Optionally, the shale shakers **8** are like any other shale shaker disclosed herein according to the present invention. One, two, or more screens in series may separate selected material (e.g., but not limited to, lost circulation material) that flows and/or is pumped to a reservoir or to the further processing apparatus **8***k*.

Referring now to FIG. **1**A, a shale shaker H according to the present invention has screens A**1**, A**2**, A**3**, A**4**, each of which is, according to the present invention, at one of four different levels (with screen or screening cloth or mesh as desired). The screens are mounted on vibratable screen mounting apparatus or "basket" B. The screens A**1**, A**2**, A**3**, A**4**, according to the present invention, may be any suitable known screen or screens, with the screen A**2** (or the screens A**2** and A**3**) used to separate lost circulation material (and/or material of similar size). The basket B is mounted on springs C (only two shown; two as shown are on the opposite side) which are supported from a frame D. The basket B is vibrated by a motor and interconnected vibrating apparatus E which is mounted on the basket B for vibrating the basket and the screens. Elevator apparatus F provides for raising and lowering of the basket end. Fluid passing through the screens A**1**, A**2**, A**3**, and A**4** flows into a receptacle R beneath the bottom screen A**4**. In certain aspects screen A**1** has the coarsest mesh of all the screens and acts as a scalping screen and the screens A**3** and A**4** provide fine screening. The exit feeds from the top sides of the screens A**1**, A**3**, A**4** may go to disposal or may be directed as described below for any embodiment of the present invention. The lost circulation material recovered from the top of the screen A**2** (or, optionally, from the tops of the screens A**2** and A**3**) may be flowed, processed and treated as described for any embodiment of the present invention. As shown, the screens A**3**, A**4** operate in series, i.e., the underflow from the screen A**3** flows down to the screen A**4**. Optionally, the screens A**3**, A**4** may be operated in parallel with each receiving a portion of screen A**2**'s underflow.

FIGS. **2**A and **2**B show a system according to the present invention which includes a shale shaker **12** with a base **14** and a screen-supporting basket **16**. A vibrator apparatus **18** vibrates the basket **16** and screens mounted in it. Four spaced-apart screens **21**-**24** are mounted in the basket **16** at different levels (e.g. spaced-apart six to eight inches) or put another way, at four different heights in the basket. In one particular embodiment the screen **21** is a scalping screen which, in one particular aspect removes relatively large pieces of material, e.g. with mesh sized so that pieces ⅛" and 1/64" are used. In one aspect, the screen **21** has a mesh size such that pieces greater than 1/16" are removed (and pieces of, among other things, solids and/or lost circulation material that are 1/16" or smaller in largest dimension pass through the screen **21** (e.g., but not limited to graphite ball lost circulation material that are 1/16" in largest dimension or slightly smaller).

The screen **22** has a mesh size as chosen for removing material of a certain largest dimension or larger, including, but not limited to solids, debris, drilled cuttings, desirable additives, and/or lost circulation material. In one aspect the mesh size is chosen in cooperation with the mesh size of the screen **21** so that the screen **22** removes lost circulation material (and solids or pieces of similar size) and, in one particular aspect the mesh size is chosen so that lost circulation material of a largest dimension of 1/16" or greater does not pass through the screen **22** and flows from the top thereof. In one aspect such lost circulation material is graphite balls.

The screens **23** and **24** further filter out solids from the flow through the screen **22** and, in certain aspects, the screens **23** and **24** act as typical standard fine screening screens used to process a mixture of drilling fluid and solids.

The exit streams from screens **21**, **23**, and **24** exit from the tops of their respective screens and flow down to a container, system or apparatus **20** for storage and/or further processing.

Drilling fluid flowing through the screens flows down to a sump or container **26** and from there to a reservoir or, in one aspect, back to an active rig mud system. The exit stream from the screen **22**, in particular aspects, has wet lost circulation material (or wet lost circulation material along with solids of similar size) of at least 50% by volume; and in one particular aspect at least 75% lost circulation material by volume (in one example, the output is 50% lost circulation material and 50% solids of similar size). In certain aspects, screen mesh size is chosen so that a relatively large percentage of the flow off the top of the screen is lost circulation material, e.g. by volume, up to 50%, 75%, or up to 90%.

Fluid with some solids therein (including the lost circulation material of a certain size, if present) that flows through the screen **21** is directed to the screen **22** by a flow-back barrier (or plate) **31**. Optionally, the flow-back barrier **31** is eliminated. The material (including lost circulation material of a certain size, if present) that exits from the top of the screen **22** is transferred to a reclamation system **40** (which, in one aspect, is, has or includes an auger apparatus **42** for moving solids to and/or from the reclamation apparatus) or flushed to a mud pit.

Fluid with solids that flows through the screen **22** is directed to the screens **23** and **24** by a flow-back barrier or plate **32**, a flow channel **32***a*, and a weir **32***b*. Fluid with solids that flows through the screen **23** is directed to the sump **26** through a channel **51** by a flow-back barrier **33** and a channel **33***a*. When the level of fluid (with material therein) exceeds the height of the weir **32***b*, part of the flow from the screen **22** flows into the flow channel **50** bypassing the screen **23** and flowing to the screen **24** (thus, the screens **23**, **24** in this manner operate in parallel). Fluid flowing through the screen **24** flows into the sump **26**. Optionally, the screen **21** includes an end weir **21***w* and fluid and material on top of the screen **21** in a pool **21***p* that exceeds the height of the weir **21***w* bypasses the screen **21** and flows to the screen **22** via a channel **17**. The flow-back barriers extend under substantially all of the surface of the particular screens under which they are located. Any one, two, or three of the flow-back barriers can, optionally, be eliminated.

The screens **21**-**24** are at typical screen tilt angles, e.g. between 6 degrees to 12 degrees from the horizontal and in certain aspects, at about 7 degrees or about 8 degrees.

A shale shaker **10***a* shown in FIG. **2**C is like the system **10**, FIG. **2**A (and like numerals **25** indicate like parts). Two screens, the screens **22** and **23**, are used in the shale shaker **10***a* to remove LCM material (and/or material of similar size). The two screens **22**, **23** act in parallel with flow from the upper screen **21** flowing both to the screen **22** and, over a weir **22***w*, to the screen **23**. Fluid flowing through the screen **22** flows to a channel **50***a* and then down to the screen **24** as does fluid flowing through the screen **23**.

FIGS. **3**A and **3**B show a shaker system **10***b* like the system **10**, FIG. **2**A (like numerals **5** indicate like parts). The shaker **10***b* has a collection chute **60** which receives material from top of a screen **21***a* (like the screen **21**, FIG. **2**A) and from which the material flows down to a cuttings ditch, pit, or collector **19**. An auger system **70** receives material from the top of a screen **22***a* (like the screen **22**) and augers the material into a conduit **70***a* from which it flows to storage or further processing apparatus **70***b* or is 10 flushed to a mud pit. The flows from the tops of screens **23***a* (like screen **23**) and **24***a* (like screen **24**), flow to the cuttings ditch (etc.) **19**. Fluid flowing through the screens flows to a sump **26***a* (like the sump **26**). In one aspect, the screen **22***a* is used to recover LCM (and/or material of similar size). Optionally, as in FIG. **2**C, both screens **22***a* and **23***a* are used to recover LCM (and/or material of similar size).

Material recovered from the top of a second screen in systems according to the present invention (e.g. from the top of the screen **8***b*, **21** or **21***a*) can, according to the present invention, be sent to additional treatment apparatus for further processing; including, but not limited to, a sprinkle-wash system for solids recovery, centrifuge(s), hydrocyclone(s), and/or magnetic separation apparatus. This material from the tops of these screens is, in one aspect, lost circulation material. In one aspect, considering the totality (100%) of the lost circulation material in a drilling fluid mixture fed to a top scalping screen of a system according to the present invention, about 97% of this lost circulation material flows to the second screen and about 95% (95% of the original totality of the material) is recovered from the top of the second screen; or optionally, a combination of similar sized material, including both LCM and other material is recovered.

FIGS. **4**A and **4**B illustrate a quad-tier system **100** according to the present invention which has screen decks **101**, **102**, **103**, and **104**. A feed **105** of a drilling fluid mixture is fed onto a first deck **101** with a plurality of screens **101***a*, **101***b*, **101***c* (may be any suitable number of screens). Drilling fluid (with some solids) flowing through the screens **101***a*-**101***c* flows to a chute **106** and from there down to the deck **102**. Overflow **107** from the deck **101** flows over a weir **108** (of a predetermined height) down to the deck **102**. Oversized material **109** flows off the top of the screen **101***c*. Drilling fluid with some solids flowing through screens **102***a* (four shown; may be any suitable number of screens) flows to chutes **116** and from there to the deck **103**. Oversize material **119** flows off the tops of screens **102***a*. A weir **118** prevents any overflow from the top of the screens **102***a* from flowing down to the deck **103**.

Drilling fluid with some solids flowing through screens **103***a* (size shown; may be any number) of the deck **103** flows to a diverter **126** and from there to a collection structure, e.g. a tank, sump or receptacle. Overflow from the top of the screens **103***a* flows to a channel apparatus **128** and from there to a channel apparatus **138** which directs this flow to the top of the deck **104**. Oversized material **129** flows off the tops of end screens **103***a*. Drilling fluid flowing through screens **104***a* (four shown; any number may be used) flows down to chutes **136** and then to the tank, sump, or receptacle. Oversized material **139** flows off tops of end screens **104***a*.

The oversized material flows, **109**, **119**, **129** and **139** flow to typical collection sump, pit tank, or receptacle or storage apparatus and/or to subsequent processing apparatus. In one particular aspect of the system **100**, the deck **101** is a coarse screening deck (e.g. but not limited to the screen **8***a*, screen A**1**, screen **21** or screen **21***a*); the deck **102** is a medium mesh screening deck (e.g. but not limited to, like the screen **8***b*, screen A**2**, screen **22**, or screen **22***a*); the deck **103** is a medium or fine screening deck (e.g., but not limited to, like the screen **8***c*, screen A**3**, screen **23** or screen **23***a*); and the deck **104** is a fine screening deck (e.g., but not limited to, like the screen **8***d*, screen A**4**, screen **24** or screen **24***a*).

FIGS. **5**A', **5**A", and **5**B illustrate a system **200** according to the present invention which is, in some ways, like the system **100**, FIG. **4**A. In the system of FIG. **4**A underflow from the deck **102** flows to both the deck **103** and the deck **104**. In the system **200** flow from the deck **101** flows to both the deck **102** and the deck **103**, with underflow from both of these decks flowing to the deck **104**.

Drilling fluid with some solids (underflow from the deck **101**) flows from the deck **101** down to the deck **102**. Overflow from the deck **102** flows via the channel apparatus **128***a* and channel apparatus **204** to the deck **103**. Underflow from the deck **102** flows to the chutes **116** and is diverted to the deck **104** by a diverter **202** (with handles **203**) and via a channel apparatus **206** and a channel apparatus **208** to the deck **104**. In one **20** aspect the diverter **202** is connected to the channel apparatus **204** (indicated by the wavy lines on both). Underflow having passed through the deck **103** and chutes **116***a* (like the chutes **116**) is diverted by a diverter **202***a* (like the diverter **202**) to the deck **104**. Underflow having passed through the deck **104**, flows to the chutes **136** and then to collection, storage, tank, or receptacle.

The various chutes, diverters, and channel apparatuses in the systems **100** and **200** are interchangeable, in one aspect, so that series or parallel flow to and from one or more selected decks is facilitated. In certain aspects, the chutes, diverters and channel apparatuses are made of metal, plastic, or composite material.

In the system **100**, FIG. **4**A, the channel apparatus **128** has three flow passages **128***a*, **128***b*, **128***c*. The diverter **126** has two flow passages **126***a*, **126***b*. The channel apparatus **138** has flow passages **138***a*, **138***b*, **138***c*. In the system **200**, FIG. **5**A, the channel apparatus **128***a* has flow channels **128***c*, **128***d*. The channel apparatus **204** has 10 flow passage **204***a*, **204***b*. The channel apparatus **206** has flow passages **206***a*, **206***b*. The channel apparatus **208** has flow passages **208***a*, **208***b*. The present invention, therefore, provides in at least certain embodiments, a system for processing a mixture of drilling fluid and solid material to separate at least one component of the mixture by size from the mixture, the system including a vibratable basket; a sump at a bottom of the basket; a plurality of spaced-apart screens including a first screen deck, a second screen deck positioned below the first screen, a third screen deck positioned below the second screen deck, and a fourth screen deck positioned below the third screen; the screens mounted in the vibratable basket and vibratable therewith; the first screen deck having screen mesh of a first size to remove from a top of the first screen deck solids from the mixture with a largest dimension equal to and larger than a first dimension so that material with a largest dimension smaller than the first dimension is passable down through the first screen deck; the second screen deck having screen mesh of a second size to remove from a top of the second screen solids from the mixture passing to the second screen deck from the first screen deck which have a largest dimension equal to or larger than the second size so that material with a largest dimension smaller than the second size is passable down through the second screen deck, material and fluid passing through the second screen deck comprising a secondary flow; diversion apparatus connected to the basket positioned for providing at least a portion of the secondary flow to the third screen deck and, selectively, a portion of the secondary flow to the fourth screen deck; the third screen deck having screen mesh of a third size, and the fourth screen deck having screen mesh of a fourth size for removing solids from the secondary flow on the top of the third screen deck and from the top of the fourth screen deck; and drilling fluid flowing through the first screen deck, the second screen deck and one of the third screen deck and fourth screen deck flowing down into the sump. Such a system may have one or some, in any possible combination, of the features and aspects described above for any system according to the present invention. The present invention, therefore, provides in at least certain embodiments, a system for processing a mixture of drilling fluid and solid material to separate at least one component of the mixture by size from the mixture, the system including: a vibratable basket; a sump at a bottom of the basket; a plurality of spaced-apart screens including a first screen deck, a second screen deck positioned below the first screen, a third screen deck positioned below the second screen deck, and a fourth screen deck positioned below the third screen; the screens mounted in the vibratable basket and vibratable therewith; the first screen deck having screen mesh of a first size to remove from a top of the first screen solids from the mixture with a largest dimension equal to and larger than a first dimension so that material with a largest dimension smaller than the first dimension is passable down through the first screen deck; the second screen deck having screen mesh of a second size to remove from a top of the second screen solids from the mixture passing to the second screen deck from the first screen deck which have a largest dimension equal to or larger than the second size so that material with a largest dimension smaller than the second size is passable down through the second screen deck, material and fluid passing through the second screen deck comprising a secondary flow; diversion apparatus connected to the basket positioned for providing at least a portion of the secondary flow to the third screen deck and, selectively, a portion of the secondary flow to the fourth screen deck; the third screen deck having screen mesh of a third size, and the fourth screen deck having screen mesh of a fourth size for removing solids from the secondary flow on the top of the third screen deck and from the top of the fourth screen deck; drilling fluid flowing through the first screen deck, the second screen deck and one of the third screen deck and fourth screen deck flowing down into the sump; wherein the first screen deck is a scalping deck; wherein the screen mesh of a second size is suitable for removing solids the size of lost circulation material, said solids including pieces of lost circulation material and pieces of material other than lost circulation material; the drilling fluid mixture introduced to the system to be treated by the system includes a first amount of lost circulation material; the second deck is able to remove a second amount of lost circulation material; the second amount at least 75% of the first amount; and reclamation apparatus for receiving the lost circulation material.

The present invention, therefore, provides in at least certain embodiments, a method for treating a mixture of drilling fluid and solid material to separate at least one component of the mixture by size from the mixture, the method including: feeding the mixture to a vibratable basket of a system, the system as any described herein according to the present invention, and the method further including flowing drilling fluid through a first screen deck, a second screen deck and one of a third screen deck and a fourth screen deck of the system down into a sump; or flowing drilling fluid through a first screen deck, and one of a second screen deck and a third screen deck flowing down into a sump.

FIGS. **6**A-**6**D show a shale shaker **310** according to the present invention which has a basket **312** vibrated by vibratory apparatus **314** and a lower sump **316** which receives fluid (or fluid and some solids) that passes through three screens **318***a*, **318***b*, **318***c* which are mounted to the basket **312** at different levels. Fluid from the screen **318***a* flows down to a flow-back barrier **317***a*, through an opening **328**, and then onto the screen **318***b*. As this fluid builds up into a pool **315***a* on the screen **318***b*, it rises to a level equal to and then greater than a top **313***a* of a weir **313**.

Fluid then flows over the top **313***a* of the weir **313** through a channel **311** to the lower screen **318***c*. The opening **328** is defined by the weir **313** and an end of the flow-back barrier **317***a*. Fluid that flows through the screen **318***b* flows down a flow-back barrier **317***b*, over an end of a diverter **320**, and down to the sump **316** via a channel **316***a*. The diverter **320** is selectively movable in holding structure **320***a* and, as in FIG.

6A, blocks an opening **322** of a channel **324** formed by spaced-apart members **325**, **326**.

As shown in FIG. **6**B, the diverter **320** prevents fluid that has exited from the bottom of the screen **318***b* from flowing onto the screen **318***c*. This fluid flows past the opening **322** into the channel **316***a*. FIGS. **6**A and **6**B illustrate a parallel fluid flow path. As shown in FIGS. **6**C and **6**D, the diverter **320** has been moved so that fluid is flowable down onto the screen **318***c* which has exited through the bottom of the screen **318***b*. This is an "in series" flow path—from the screen **318***a* to the screen **318***b* to the screen **318***c*—for fluid down to the sump **316**.

The diverter **320** can be manipulated and moved through an open end access area **329** (FIG. **6**F) of the basket **312**. As shown in FIG. **6**E, the diverter **320** has a solid chute portion **320***a* for facilitating fluid flow and two handles **320***b* projecting from the chute portion **320***a*.

The angle from the horizontal of the screen **318***b* coupled with the height of the weir **313** determines the depth of the pool **315***a* and of a lower edge **318***e* of a beach area **318***f* on the screen **318***b* (e.g., see FIG. **6**C).

Fluid flowing through the screen **318***c* flows down a flow-back barrier **317***c* into the sump **316**. Solids (wet to some degree) flow off the ends of the screens as indicated by the arrows W. The diverter **320** is mounted between rails **321** of the holding structure **320***a* (see, e.g. FIG. **6**G) and clamping apparatuses **320***p*, **320***s* are used to hold the diverter **320** in place. Any suitable clamping apparatus may be used including, without limitation, pneumoseal apparatuses. Clamping apparatuses **310***p* hold the screens in place.

FIGS. **7**A and **7**B show a shale shaker **340**, according to the present invention, with a basket **342** vibrated by vibratory apparatus **344**. Screens **346**, **347**, **348** are mounted in the basket with a flow-back barrier **345** beneath the screen **346** and flow-back barrier **343** beneath the screen **347**. A weir **341** with a top end **341***a* defines (with an end **342***a* of the basket **342**) a flow channel **349** for fluid flowing over the top **341***a* of the weir **341** from a pool **351** of fluid on the screen **347**. Fluid flowing down in the channel **349** flows to the lowermost screen **348**. Fluid flowing through the screen **348** flows into a sump **356**. The screen **347** has flow barrier **352** (see FIG. **7**C) connected therebelow with an end **353** which, in the position shown in FIG. **7**A, blocks an opening **354** (see, FIG. **7**B) so that fluid flowing in the channel **349** cannot flow into a channel **359**. Also, with the opening **354** blocked, fluid flowing down through the screen **347** flows along the flowback barrier **343** to the opening **354**, into the channel **359**, and then into the sump **356**. Thus the flow mode for the screens **347** and **348** as shown in FIG. **7**A is parallel—fluid flowing through the screen **347** does not flow to the screen **348**.

As shown in FIG. **7**B, the screen **347** does not have the flow barrier **352** below it and the channel **359** is closed to fluid flow by a flow barrier **362**. With the channel **359** closed by the flow barrier **362** and with the end **353** removed from the opening **354**, fluid flowing through the screen **347** flows onto the screen **348** and thus the flow mode, as shown in FIG. **7**B, is in series for the screens **347**, **348**.

As shown in FIG. **7**C, for parallel flow, the flow barrier **352** has a body **363** with a flow channel **355** therethrough; a solid portion **350**; and an end connection **357** for connection to the screen **347**. As shown in FIG. **7**D the flow barrier **362** has a body **358** with a flow channel **360** therethrough and a connection **361** for connection to the screen **347**. FIG. **7**D illustrates the flow path for series flow.

FIGS. **8**A and **8**B show a shale shaker **370** according to the present invention with a basket **372** vibrated by vibratory apparatus **374**. Screens **376**, **377**, **378** are mounted in the basket with a flow-back barrier **375** beneath the screen **376** and flow-back barrier **373** beneath the screen **377**.

A weir **371** with a top end **371***a* defines (with an end **372***a* of the basket **372**) a flow channel **379** for fluid flowing over the top **371***a* of the weir **371** from a pool **381** of fluid on the screen **377**. Fluid flowing down (FIG. **8**A) in the channel **379** flows to the lowermost screen **378**. Fluid flowing through the screen **378** flows along a flowback barrier **394** into a sump **386**.

The screen **377** has an insert **390** at an end **377***a* which is in the position shown in FIG. **8**A. Fluid flowing through the screen **377** flows into a flow channel **393** of a channel apparatus **391** (see FIG. **8**D) positioned in an opening **397** at an end **378***a* of the screen **378** and then into the sump **386**. Pneumoseal apparatus **389***p*, **389***s* facilitates the clamping in place of the screens and inserts, and the maintenance of the screens and inserts in a desired position.

Fluid from the pool **381** flowing over the top **371***a* of the weir **371** flows in the channel **379** down to the screen **378**. Fluid flowing through the screen **378** flows into the sump **386**. Thus the flow from the screen **376** to and through the screens **377**, **378** is in a 10 parallel flow mode.

As shown in FIG. **8**B, the insert **390** and the channel apparatus **391** have been removed, and the screen **377** has been moved down so that the end **377***a* now occupies the position of the insert **390**. Fluid flowing through the screen **376** flows down to the screen **377**. Then fluid flowing through the screen **377** flows down to the screen **378** through an opening **374**. An insert **392**, FIG. **8**E, replaces the channel apparatus **391** at the lower end **378***a* of the screen **378** and blocks flow through the opening **397** (see FIG. **8**A).

FIGS. **9**A-**9**D show a shaker **400** with a sump **416** and basket **402** vibrated by vibratory apparatus **404**. Screens **411**, **412**, and **413** are mounted in the basket **402**. A flowback barrier **401** is below the screen **411**, a flowback barrier **414** is below the screen **412**, and a flowback barrier **415** is below the screen **413**. A weir **405** having a top end **405***a* with an end portion **402***a* of the basket **402** defines a channel **409** through which flows fluid coming over the top end **405***a* of the weir **405** from a pool **406** of fluid on the screen **412**. Fluid flows down and out of the channel **409** to contact and flow through an insert **417** positioned at an end **412***a* of the screen **412**. Fluid flows through a passageway **418** in the insert **417** (see FIGS. **9**E-**9**F) to a channel **419** and down to the screen **413**. Thus fluid flows from the screen **411** to both the screens **412** and **413** in a parallel flow mode. Fluid flowing through the screen **412** flows to and through channels **417***a*, **417***b* in the insert **417**, from there into a channel **410**, and down to the sump **416**.

FIGS. **9**C and **9**D show the shaker **400** in a series flow mode. As shown in FIGS. **9**C and **9**D, an insert **424** (see FIGS. **9**G and **9**H) is positioned at the end **412***a* of the screen **412**, replacing the insert **417**. Insert **424** blocks the flow of any fluid that may overflow the top end **405***a* of the weir **405** and enter the channel **409**. Fluid flowing from the screen **412** flows down the flowback barrier **414** therebelow, passes through a channel **425** in the insert **424** and then down, via the channel **419** onto the screen **413**. As in FIGS. **9**A and **9**B, pneumoseal apparatuses **400***p*, **400***s* hold screens and inserts in place.

FIGS. **10**A and **10**B show a shale shaker **430**, in parallel flow mode in FIG. **10**A and in series flow mode in FIG. **10**B. The shale shaker **430** has a basket **438** vibrated by a vibratory apparatus **434**. A flowback barrier **437** is below a screen **431**; a flowback barrier **435** is below a screen **432**; and a flowback barrier **436** is below a screen **433**. The flowback barrier **435** has a channel **435***a* in an end **435***b*. Pneumoseal apparatuses

430*p*, 430*s* hold screens and inserts in place. Fluid flowing through the screen **431** flows to both the screen **432** and to the screen **433** from a pool **429** on the screen **432**, over a weir **444**, through a channel **427**, and through an opening **439***a* in an insert **439** (see FIGS. **10**C, **10**D) positioned at an end **432***a* of the screen **432**. Fluid flowing through the screen **432** flows to a channel **441** of a channel apparatus **442** (see FIG. **10**E) positioned at an end **433***a* of the screen **433** and then to a sump **446**. Fluid flowing through the screen **433** flows down to the sump **446**.

As shown in FIG. **10**B, an insert **448** (see FIG. **10**F) is positioned at the end **432***a* of the screen **432**, replacing the insert **439**, and blocks flow through the channel **427**. Additionally, an insert **449** (see FIG. **10**G) is positioned at the end **433***a* of the screen **433**, replacing the channel apparatus **442**, and blocks flow through an opening **449***a* (see FIG. **10**A) so that all fluid flowing from the screen **431** flows to the screen **432**. Via the opening **435***a*, all fluid flowing from the screen **432** flows to the screen **433**.

FIGS. **11**A and **11**B show a shale shaker **450** with a basket **452** vibrated by a vibratory apparatus **454**. A flowback barrier **457** is beneath a screen **461** and a flowback barrier **458** is beneath a screen **462**. Fluid flowing through a screen **463** flows into a sump **456**. Pneumoseal apparatuses **450***p*, **450***s* hold screens and inserts in place.

Fluid from a pool **459** on the screen **462** overflows a top end **464***a* of a weir **464**, through a channel **465**, onto the screen **463** (as shown in FIG. **11**A). Fluid flowing through the screen **462** flows through a channel **453** in an insert **451** (see FIG. **11**D) and then into the sump **456** (not onto the screen **463**). The insert **451** is mounted in a mount **467** and the channel **453** is in fluid communication with a flow channel **471**, permitting the fluid flowing through the screen **462** to flow into the channel **471**. Thus, the fluid flowing through and then down from the screen **461** flows both to the screen **462** and (over the weir **464**) to the screen **463**, i.e. in a parallel flow mode. An insert **474** (see FIG. **11**C) at the end **462***a* of the screen **462** holds the screen **462** in such a position that height of the pool **459** makes possible the flow of fluid over the weir **464**, so that series or parallel flow can be achieved.

FIG. **11**B illustrates a series flow mode for the shaker **450**. An insert **472** now replaces the insert **451** in the mount **467**, and blocks the opening to the channel **471** so that fluid flowing through the screen **462** flows down onto the screen **463** (not directly into the sump **456** through the channel **471**). Additionally, the insert **474** has been removed and the screen **462** has been moved down so that the end **462***a* now occupies the position of the insert **474**. Some overflow, if any, from the pond on the screen **462** could flow over the weir **464** down to the screen **463**. Optionally a cut-out portion **479** of the insert **472** provides a handle (see FIG. **11**E). Furthermore, in other embodiments, the insert **451** may be designed so that when changing the shaker **450** from a parallel flow mode to a series flow mode, the insert **451** may be removed, reversed, and reinstalled so that the channel **453** is no longer positioned above the flow channel **471**, and therefore no longer provides fluid communication thereto. Instead, the insert **451** may be designed so as to block the opening to the channel **471**, thereby facilitating series flow from the screen **462** to the screen **463**, as described above.

FIGS. **12**A and **12**B show the shale shaker **480** with a basket **482** vibrated by vibratory apparatus **484**. Fluid flowing through a lowermost screen **493** flows into a sump **496**. A flow-back barrier **481** is beneath a top screen **491** and a flow-back barrier **483** is beneath a middle screen **492**. A flow-back barrier **486** is beneath the screen **493**. Pneumoseal apparatuses **480***p*, **480***s* hold screens and inserts in place. In a parallel flow mode as illustrated in FIGS. **12**A, **12**B, fluid flowing through the screen **491** flows to both the screen **492** and from a pool **489** on the screen **492** over a top end **487***a* of a weir **487** via a flow channel **488** down to the screen **493**. An insert **498** (see FIGS. **12**E, **12**F) in a mount **497** has an opening **498***a* through which fluid from the channel **488** flows to the screen **493**. At the same time, fluid from the screen **492** is deflected by a plate portion **498***d* of the insert **498** and flows through openings **498***b* to a channel **485** and to the sump **496**.

FIGS. **12**C and **12**D show the shale shaker **480** in series flow mode. As shown in FIG. **12**C, fluid has flowed through the screen **491** down to the screen **492**, and the insert **498** has been flipped and rotated in the mount **497** (as shown in FIG. **12**G) so that the positions of the openings **498***a* and **498***b* relative to the flow channels **488** and **485**, respectively, have been reversed. Fluid flowing through the screen **492** flows to the opening **498***a* in the insert **498** and then down to the screen **493**. In the reversed installation of the insert **498** shown in FIG. **12**C, plate portions **498***c* on either side of the opening **498***a* in the insert **498** (see FIG. **12**G) can block fluid flow through the channel **485**. Similarly, as shown in FIG. **12**D, the plate portion **498***d* between the two openings **498***b* in the insert **498** can also block fluid flow from the channel **488**.

FIGS. **13**A and **13**B show a shale shaker **500** in a parallel flow mode. The shaker **500** has a basket **507** and screens **501-503** vibrated by a vibratory apparatus **504**. Flowback barriers **511-513** are, respectively, located under the screens **501-503**. An insert **530** in a mount **540** is used to change operational mode from series to parallel and vice-versa. Pneumoseal apparatuses **500***p*, **500***s* hold screens in place.

As shown in FIG. **13**A fluid from the screen **501** flows both to the screen **502** and to the screen **503** (from a pool **509** on the screen **502**, over a weir **534**, through a channel **505**, and through an opening **530***b* in the insert **530**). As shown in FIG. **13**B fluid from the screen **502** flows to the sump **506** (down the flowback barrier **512**, through openings **530***a* in the insert **530**, to a channel **551** of a channel apparatus **550**, and to the sump **506**). Fluid from the screen **503** flows down the flowback barrier **513** to the sump **506**.

FIGS. **13**C and **13**D illustrate the shaker **500** in a series flow mode. As shown in FIG. **13**C, the insert **530** (turned around) has been moved forward in the mount **540** so that the opening **530***b* is no longer aligned with the channel **505**, and the openings **530***a* are no longer aligned with the channel **551**. In this position, the insert **530** blocks fluid flow from the channel **505** so that only the screen **502** receives the fluid flowing from the screen **501**. The insert **530** also blocks fluid flow through the channel **551** so that all the fluid flowing from the screen **502** flows to the screen **503**. As shown in FIG. **13**E, the insert **530** has openings **530***a* (for flow from screen **502** to the channel **551**) and an opening **530***b* (for flow from the pool **509** through the channel **505**) to facilitate operation of the shale shaker **500** in a parallel flow mode.

As shown in FIG. **13**E, the insert **530** has fluid flow channels **530***c*. Any screen assembly, any diverter, any pair of screen assemblies, and/or any insert according to the present invention (including, without limitation those of FIGS. **6**A-**13**E) may be used with any shaker or system according to the present invention disclosed herein. The present invention, therefore, provides in at least certain embodiments, a system for processing a mixture of drilling fluid and solid material to separate at least one component of the mixture by size from the mixture, the system including: a vibratable basket for receiving an input flow of drilling fluid with solids therein; a plurality of spaced-apart screen assemblies including a first screen assembly and a second screen assembly positioned below the first screen assembly; the screen assemblies mounted in the vibratable basket and vibratable therewith; conversion apparatus associated with the screen assemblies for selectively controlling the input flow to select one of series flow and parallel flow to the screen assemblies; drilling fluid flowable through the first screen assembly; and drilling fluid flowable through the second screen assembly and flowable down therefrom. Such a system may one or some, in any possible combination, of the following: a system flow channel between the first screen assembly and the second screen assembly, the conversion apparatus including holding structure above the second screen assembly, a diverter held by the holding structure, the diverter having a diverter channel therethrough through which fluid is flowable from the first screen assembly through the system flow channel down to the second screen assembly for series flow of the input flow from the first screen assembly to the second screen assembly, a weir adjacent the first screen assembly forming a barrier to facilitate maintenance of a pool of drilling fluid and solids on the first screen assembly, and the diverter having a blocking portion, the diverter movable to block flow through the system channel so that the pool rises and drilling fluid with solids bypasses the first screen assembly and flows to the second screen assembly for parallel flow of the input flow to both screen assemblies; the holding structure having spaced-apart rails and having an end opening, and the diverter located between the rails and having handle apparatus at the end opening, the handle apparatus accessible for moving the diverter with respect to the system flow channel; flow-back apparatus beneath the first screen assembly for directing flow passing through the first screen assembly to the system flow channel; a sump beneath the second screen assembly for receiving flow passing through the screen assemblies; a parallel flow channel adjacent the screen assemblies for directing flow from the pool to the second screen assembly bypassing the first screen assembly during parallel flow of the system; holding structure above the second screen assembly, and clamping apparatus for holding the diverter in the holding structure; wherein the first screen assembly includes a scalping screen; wherein the second screen assembly includes a screen with second screen mesh of a size suitable for removing solids the size of lost circulation material; a system flow channel between the first screen assembly and the second screen assembly through which fluid is flowable from the first screen assembly to the second screen assembly, the conversion apparatus having a body, the body having a blocking portion for blocking flow to the system flow channel to effect system parallel flow of the input flow to both screen assemblies, and the body having a flow duct for receiving flow from the first screen assembly which is flowable through the duct to the second screen assembly for system series flow to the screen assemblies; a duct blocker for blocking flow through the duct; and/or the conversion apparatus having a body, a first flow channel through the body for effecting system parallel flow to the screen assemblies, and a second flow channel through the body for effecting system series flow to the screen assemblies.

The present invention, therefore, provides in at least certain embodiments, a system for processing a mixture of drilling fluid and solid material to separate at least one component of the mixture by size from the mixture, the system including: a vibratable basket for receiving an input flow of drilling fluid with solids therein; a plurality of spaced-apart screen assemblies including a first screen assembly and a second screen assembly positioned below the first screen assembly; the screen assemblies mounted in the vibratable basket and vibratable therewith; conversion apparatus associated with the screen assemblies for selectively controlling the input flow to select one of series flow and parallel flow to the screen assemblies; drilling fluid flowable through the first screen assembly and drilling fluid flowable through the second screen assembly and down therefrom; a system flow channel between the first screen assembly and the second screen assembly; the conversion apparatus having a body, a first flow channel through the body for effecting system parallel flow to the screen assemblies, a second flow channel through the body for effecting system series flow to the screen assemblies; flow-back apparatus beneath the first screen assembly for directing flow passing through the first screen assembly to the system flow channel; a sump beneath the second screen assembly for receiving flow passing through the screen assemblies; and a parallel flow channel adjacent the screen assemblies for directing flow from the pool to the second screen assembly bypassing the first screen assembly during parallel flow to the screen assemblies

The present invention, therefore, provides in at least certain embodiments, a conversion apparatus for a system for processing a mixture of drilling fluid and solid material to separate at least one component of the mixture from the mixture, the system including a vibratable basket for receiving an input flow of drilling fluid with solids therein, a plurality of spaced-apart screen assemblies including a first screen assembly and a second screen assembly positioned below the first screen assembly, the screen assemblies mounted in the vibratable basket and vibratable therewith, drilling fluid flowable through the first screen assembly and the second screen assembly down therefrom, the conversion apparatus associated with the screen assemblies for selectively controlling the input flow to select one of series flow and parallel flow, the conversion apparatus including: a body, a first flow channel through the body for effecting system parallel flow to the screen assemblies, and a second flow channel through the body for effecting system series flow to the screen assemblies.

The present invention, therefore, provides in at least certain embodiments, a method for treating a flow of drilling fluid with solids, the method including: introducing the flow of drilling fluid with solids to a system for separating at least one component from the flow, the system as any disclosed herein according to the present invention; the method further including: selecting one of a system series flow to screen assemblies of the system or a system parallel flow to the screen assemblies using a conversion apparatus; flowing drilling fluid with solids to the screen assemblies; and screening the flow to each screening assembly. Such a method may one or some, in any possible combination, of the following: wherein the conversion apparatus has a body, a first flow channel through the body for effecting system parallel flow to the screen assemblies, and a second flow channel through the body for effecting system series flow to the screen assemblies, the method further including selecting the first flow channel for system parallel flow or selecting the second flow channel for system series flow; wherein the system further has flow-back apparatus beneath the first screen assembly for directing flow passing through the first screen assembly to the system flow channel, the method further including directing flow from the first screen assembly to the system flow channel; wherein the system further has a sump beneath the second screen assembly, the sump receiving flow passing through the screen assemblies; wherein the system further has holding structure above the second screen assembly, and clamping apparatus for holding the diverter in the holding structure, the method further including clamping the diverter with the clamping apparatus; and/or wherein the first screen assembly includes a scalping screen, and wherein the second screen assembly includes a screen with second screen mesh of a second size suitable for removing solids the size of lost circulation material.

FIG. **14** shows an apparatus for separating solids from a solids laden drilling mud, generally referred to as a shale shaker and identified herein by reference H**1**. The shale shaker H**1** comprises a base D**1** having an open bottom R**1** arranged above a collection receptacle (not shown) for receiving screen drilling mud. A basket B**1** is arranged on springs C**1** on the base D**1**. A vibratory apparatus E**1** is arranged on top of the basket B**1**. The vibratory apparatus E**1** comprises an electric or hydraulic motor M**1** rotating offset clump weights hidden within casing **51**, which induce a motion in the basket D**1**. An upper, upper middle, lower middle and lower screen assemblies Z**1**, Z**2**, Z**3**, Z**4** are arranged in the basket D**1** and fixed thereto in rails (not shown) so that the motion induced in the basket is transferred to the screen assemblies Z**1**, Z**2**, Z**3**, Z**4**. Solids laden drilling fluid is fed on to the screen assemblies Z**1**-Z**4** from a feed chamber F**1** at a feed end of the apparatus. The motion induced in the screen assemblies Z**1**-Z**4** facilitates separation of solids from drilling mud. Screened drilling mud passes through the screen assemblies into the collection receptacle (not shown) and solids climb along the screen assemblies Z**1**-Z**4** to a discharge end P**1** of the shale shaker and into a skip, ditch or other cuttings transfer apparatus (not shown).

FIGS. **15**A and **15**B show a shale shaker **1010** having a base **1020** and a basket **1030** arranged thereon on springs (not shown). The basket **1030** comprising a scalping deck **1011**, an upper primary deck **1012** and a lower primary deck **1013**. The upper primary deck **1012** has a left-hand side **1012***a* and a right-hand side **1012***b*. The lower primary deck has a left-hand side **1013***a* and a right-hand side **1013***b*. Solids laden drilling fluid is introduced to a feed end **1014** of the shale shaker **1010** from a feeder (not shown) on to a scalping screen **1015** arranged in C-shaped channels **1016** of the scalping deck **1011**. An expandable pneumatic bladder **1017** is arranged in a top part of the C-shaped channels **1016** to clamp the scalping screen **1015** therein. Alternatively, a wedge may be used to secure the scalping screen **1015** in the C-shaped channels **1016**. The scalping screen **1015** comprises a screen having relatively large openings for inhibiting large particles from passing though on to the primary decks, but allowing some solids and drilling mud therethrough. The scalping deck **1011** and the screen **1015** thereon is arranged at an uphill tilt of approximately one degree from horizontal, although the scalping screen **1015** and scalping deck **1011** may be arranged horizontally, slightly downhill or at a slightly greater uphill angle. Vibratory apparatus **1018** fixed to the basket **1030** induces motion therein. The motion facilitates separation of large solids from the solids laden drilling mud and induces movement in the large solids along the scalping screen **1015** from the feed end **1014** to the discharge end **1019** of the shale shaker. The large solids may be caught in a ditch or on a conveying means and further processed or used in other operations. The solids laden drilling fluid which passes through the scalping screen **1015** falls on to a flow tray **1021** which directs the solids laden drilling fluid to the feed end **1014** of screen assemblies **1022***a* and **1022***b* in the upper primary deck **1012**. A weir **1023** is arranged at the feed end of the primary deck **1012** to retain the solids laden drilling fluid. If the level of the solids laden drilling fluid rises beyond the height of the weir **1023**, solids laden drilling fluid passes thereover into a duct **1024** and on to screen assemblies **1025***a* and **1025***b* in the lower primary screen deck **1013**. The screen assemblies **1022***a*, **1022***b* and **1025***a* and **1025***b* are preferably of the same type and have the same screen mesh thereon.

A gate valve **1026** in the form of a slideable tray, is in a closed position to run the shale shaker in a parallel mode. Screened drilling mud falls through the screen assemblies **1022***a* and **1022***b* in the upper screen deck on to a flow tray **1027** and over the closed gate valve **1026**, and into a duct **1028** which runs parallel to the duct **1024**. However, duct **1028** leads to the bottom of the basket and directly into the collection receptacle (not shown) therebelow. Solids fall off the discharge end **1031** of upper screen deck **1012** and discharge end **1032** of the lower screen deck **1013** and into a skip or other conveying apparatus for conveying the solids for further processing or re-use. The gate valve **1026** may be retracted to allow drilling mud screened by the screen assemblies **1022***a* and **1022***b* in the upper screen deck **1012** to be further screened by screen assemblies **1025***a* and **1025***b* on the lower screen deck **1013**. The shale shaker thus runs in a series mode. In this situation, it is preferable to use a finer screen mesh in the screen assemblies **1025***a* and **1025***b* than the screen mesh used in screen assemblies **1022***a* and **1022***b*. Drilling mud screened by the screen assemblies **1022***a* and **1022***b* in the upper screen deck **1012** flows in the flow tray **1027** and into a duct **1029**, which directs the screened drilling mud on to the feed end **1014** of the screen assemblies **1025***a* and **1025***b* in the lower screen deck **1013**. Sized solids fall off the discharge end **1031** of upper screen deck **1012** into a conveyor (not shown) to be conveyed and mixed into a fresh batch of drilling mud for re-circulation. These sized solids are used to block cracks in the formation as hereinbefore described. Solids discharged from the discharge end **1032** of the lower screen deck **1013** are conveyed in a separate conveyor or added to a skip for further processing or used for other purposes.

Referring to FIGS. **16**, **16**A, **16**C, **17** and **18**, there is shown a basket **1100** of a shale shaker. The basket **1100** comprising a scalping deck **1111**, an upper primary deck **1112** and a lower primary deck **1113**. The upper primary deck **1112** has a left-hand side **1112***a* and a right-hand side **1112***b*. The lower primary deck **1113** has a left-hand side **1113***a* and a right-hand side **1113***b*. Solids laden drilling fluid is introduced to a feed end of the shale shaker **1114** from a feeder (not shown) on to a scalping screen **1115** arranged in C-shaped channels **1116** of the scalping deck **1111**. An expandable pneumatic bladder **1117** is arranged in a top part of the C-shaped channels **1116** to clamp the scalping screen **1115** therein. Alternatively, a wedge may be used to secure the scalping screen **1115** in the C-shaped channels **1116**. The scalping screen **1115** comprises at least one layer of screen material, such as wire mesh having relatively large openings for inhibiting large particles from passing though on to the upper and lower primary decks **1112** and **1113**, but allowing some solids and drilling mud therethrough. The scalping deck **1111** and the scalping screen **1115** thereon is arranged at an uphill tilt of approximately one degree from horizontal, although the scalping screen **1115** and scalping deck **1111** may be arranged horizontally, slightly downhill or at a slightly greater uphill angle. Vibratory apparatus **1118** fixed to the basket **1100** induces motion therein. The motion facilitates separation of large solids from the solids laden drilling mud and induces movement in the large solids along the scalping screen **1015** from the feed end **1114** to the discharge end **1119** of the shale shaker. The large solids may be caught in a skip, ditch or on a conveying means (not shown) and further processed or used in other operations. The solids laden drilling fluid which passes through the scalping screen **1115** falls on to a flow tray **1121** which directs the solids laden drilling fluid over a closed distribution gate valve in the form of a slideable tray distribution gate tray **1101**, and as shown in FIGS. **17** and **18**, through eight duct openings **1102***a*, **1102***b*, **1102***c*, **1102***d* and **1103***a*, **1103***b*, **1103***c* and **1103***d* of a manifold **1104** arranged between side walls **1105** and **1106** of the basket **1100**. Preferably, the eight duct openings **1102***a*, **1102***b*, **1102***c*, **1102***d* and **1103***a*, **1103***b*, **1103***c* and **1103***d* are located flush with or slightly below the flow tray **1121** and distribution gate tray **101** tray **1101**. The openings **1102***a*, **1102***b*, **1102***c*, **1102***d* and **1103***a*, **1103***b*, **1103***c* and **1103***d* may be arranged vertically in the manifold **1104**, with the openings **1102***a*, **1102***b*, **1102***c*, **1102***d* and **1103***a*, **1103***b*, **1103***c* and **1103***d* each having a lower lip substantially flush with or slightly below the distribution gate tray **1101**. The solids laden drilling fluid flows in approximately equal quantities through duct openings **1102***a* to **1102***d* into ducts **1107***a* to **1107***d* and through openings **1103***a* to **1103***d* into ducts **1108***a* to **1108***d*. Approximately an eighth of the flow solids laden drilling fluid passes into each opening **1102***a* to **1102***d* and **1103***a* to **1103***d*. Ducts **1107***a* and **1107***b* lead to respective discharge outlets **1109***a* and **1109***b*, discharging solids laden drilling fluid on to a feed end of screens **1122***a* of the upper primary deck **1112**. Ducts **1107***c* and **1107***d* lead to respective discharge outlets **1109***c* and **1109***d*, discharging solids laden drilling fluid on to a feed end of screens **1122***b* of the upper primary deck **1112**. Ducts **1108***a* and **1108***b* merge into duct **1110***a* and ducts **1108***c* and **1108***d* merge into duct **1110***c*, discharging solids laden drilling fluid through discharge opening **1110***b* and **1110***d* on to feed ends of screens **1125***a* and **1125***b* respectively of the lower primary deck **1113**.

Drilling mud screened by screens **1122***a* and **1122***b* falls through the screens **1122***a* and **1122***b* on to a flow tray **1127** and flows down along over selector gate trays **1126***a* and **1126***b* respectively and into fluid discharge openings **1124***a*, **1124***b* and **1124***c*. Screened drilling fluid passes through opening **1124***a* and **1124***b* into fluid discharge duct **1124***d* and is directed into a sump **1157** (see FIG. **21**), screened drilling fluid also passes through opening **1124***c* and into fluid discharge duct **1124***e* which also directs screened drilling fluid into the sump **1157** (see FIG. **21**) arranged below the basket **1100**. Solids laden drilling fluid screened by screens **1125***a* and **1125***b* falls through the screens **1125***a* and **1125***b* on to a flow tray **1128** which discharges the screened drilling fluid through opening **1129** into the sump (not shown) or collection receptacle (not shown).

Solids screened by the screens **1122***a* and **1122***b* and screens **1125***a* and **1125***b* are discharged over solids discharge end **1130** and **1131** respectively and into a ditch, skip or other solids collection or conveying apparatus.

In this "parallel" mode of operation, both upper and lower screen decks are used to screen the same solids laden drilling fluid, which has simply had large solids removed by the scalping screen **1115**. Thus, in this parallel mode, the screen assemblies **1122***a*, **1122***b* and **1125***a* and **1125***b* are preferably of the same type and have the same screen mesh thereon.

Referring to FIG. **16**B, a "series" mode of operation is shown. Distribution gate tray **1101** and selector gate trays **1126***a* and **1126***b* are retracted. The distribution gate tray **1101** is arranged in a rail **1132**. The distribution gate tray **1101** is retracted along the rail **1132** by activation of an actuator (not shown), which may be pneumatic, hydraulic, electric or mechanical and may be activated by a switch (not shown) on the shale shaker or by remote control from a control room. Selector gate trays **1126***a* and **1126***b* are arranged in respective sets of rails **1133***a* and **1133***b*. The selector gate trays **1126***a* and **1126***b* are retracted simultaneously along the sets of rails **1133***a* and **1133***b* by activation of an actuator (not shown), which may be pneumatic, hydraulic, electric or mechanical and may be activated by a switch (not shown) on the shale shaker or by remote control from a control room.

In this "series" mode, the distribution gate tray **1101** and selector gate trays **1126***a* and **1126***b* are retracted revealing an opening **1134**. Solids laden drilling fluid flows through the opening **1134** over an upper diverter tray **1135** and on to a feed end of the screens **1122***a* and **1122***b* on the upper screen deck **1112**. Screened drilling fluid flowing through the screens **1122***a* and **1122***b* flows on to the flow tray **1127** and through an opening **1136** revealed by the retracted selector gate trays **1126***a* and **1126***b* over a lower diverter tray **1137** on to a feed end of the screens **1125***a* and **1125***b* on the lower screen deck **1113**.

In this "series" mode of operation, the screens **1122***a* and **1122***b* on the upper screen deck **1112** are used for the first "cut" to remove larger solids and the screens **1125***a* and **1125***b* on the lower screen deck **1113** are used to make a finer cut. Thus in series mode, the screens **1125***a* and **1125***b* will be of finer mesh size than the screens **1122***a* and **1122***b*.

The solids removed by the screens **1122***a* and **1122***b* are thus sized solids, which can be reused in the screened drilling mud. The sized solids are useful for, amongst other things, as Wellbore Strengthening Materials to lodge or block cracks in the walls of the wellbore as the drilling mud is circulated.

FIG. **19**A shows in cross-section the solids discharge end of the basket **1100**, taken through side **1112***a*. Solids are conveyed uphill along the top surface of the screens **1122***a* and **1122***b* by the vibratory motion induced in the screens **1122***a* and **1122***b* by the vibratory apparatus **1118**. The solids fall from screens **1122***a* and **1122***b* on to respective parallel diverter plates **1150** (only side **1112***a* shown) fitted over a trough **1151** and trough **1151***a*. The parallel diverter plate **1150** is angled at approximately twenty five degrees from horizontal to facilitate directing the solids out of the basket and into a skip, ditch or means for conveying the solids. The parallel diverter plate **1150** is fitted over the trough **1151** preferably when the shale shaker is in the parallel mode of operation.

FIG. **19**B shows the diverter plate **1150** removed and replaced with series diverter plates **1152** and **1152***a* installed at the end of the basket **1100**. The series diverter plates **1152** and **1152***a* are fitted at the discharge end of the basket **1100** to direct solids from screens **1122***a* and **1122***b* into troughs **1151** and **1151***a*. The solids flow through the trough **1151** and **1151***a*, which have a floor **1153**, **1153***a* which slope towards respective openings **1154** and **1154***a* in sides **1105** and **1106**. Flexible duct connectors **1155** and **1155***a* lead from openings **1154** and **1154***a* respectively to sump channels **1156** and **1156***a* in a base **1158**. The basket **1100** is isolated from the base **1158** on four springs **1159** and **1159***a* (only two shown). The sump channels **1156** and **1156***a* led into sump **1157** fsee FIG. **21**) beneath the basket **1100**. The generally smaller solids discharging from discharge end **1131** of the lower screen deck **1113** fall into the skip, ditch or other solids conveying apparatus to be disposed of or further processed form construction or industrial use. Thus the solids sized between the scalping deck **1111** and the upper primary deck **1112** are returned into the screened drilling mud in the sump **1157** to be re-circulated in a wellbore. The flow of solids through the troughs **1151** and **1151***a* is facilitated by fully screened drilling fluid jetted through jetting nozzles **1160** and **1160***a* respectively. The jetting nozzles are connected to drilling mud supply hoses (not shown) and a pump (not shown). Jetting nozzles **1162** are also provided in the sump channels **1156** and **1156***a* after the flexible duct connectors **1155** and **1155***a*, respectively, to facilitate flow of solids into the sump **1157**.

In conclusion, therefore, it is seen that the present invention and the embodiments disclosed herein and those covered by the appended claims are well adapted to carry out the objectives and obtain the ends set forth. Certain changes can be made in the subject matter without departing from the spirit and the scope of this invention. It is realized that changes are possible within the scope of this invention and it is further intended that each element or step recited in any of the following claims is to be understood as referring to the step literally and/or to all equivalent elements or steps.

It is the express intention of the applicant not to invoke 35 U.S.C. §112, paragraph 6 for any limitations of any of the claims herein, except for those in which the claim expressly uses the words 'means for' together with an associated function. In this document, the word "comprising" is used in its non-limiting sense to mean that items following the word are included, but items not specifically mentioned are not excluded. A reference to an element by the indefinite article "a" does not exclude the possibility that more than one of the element is present, unless the context clearly requires that there be one and only one of the elements.

Whereas the present invention has been described in particular relation to the drawings attached hereto, it should be understood that other and further modifications apart from those shown or suggested herein, may be made within the scope and spirit of the present invention.

What is claimed is:

1. A shale shaker for separating solids from solids laden drilling fluid, the shale shaker comprising:

- a basket;
- a first screen deck mounted in said basket;
- a second screen deck mounted in said basket and positioned below said first screen deck;
- a flow manifold comprising a plurality of first flow ducts and a plurality of second flow ducts interleaved with said first flow ducts, wherein said flow manifold is adapted to receive an unchanneled flow of solids laden drilling fluid, said plurality of first flow ducts being adapted to receive a first portion of said unchanneled flow and channel said first portion to said first screen deck, and said plurality of second flow ducts being adapted to receive a second portion of said unchanneled flow and channel said second portion to said second screen deck; and
- a non-channeled flow tray mounted in said basket and positioned above said first screen deck, wherein said non-channeled flow tray is adapted to feed said unchanneled flow to said flow manifold.

2. A shale shaker as claimed in claim **1**, wherein each of said plurality of first flow ducts comprises a respective first duct opening and each of said plurality of second flow ducts comprises a respective second duct opening.

3. A shale shaker as claimed in claim **2**, wherein said plurality of first duct openings are interleaved with said plurality of second duct openings, said plurality of first and second duct openings being arranged substantially perpendicularly to a flow direction of said unchanneled flow of solids laden drilling fluid.

4. A shale shaker as claimed in claim **2**, wherein said non-channeled flow tray has a floor and at least one of said pluralities of first and second duct openings is substantially planar with said floor of said non-channeled flow tray.

5. A shale shaker as claimed in claim **1**, wherein said non-channeled flow tray has a feed end and a discharge end, the pluralities of first and second flow ducts being arranged at said discharge end of said non-channeled flow tray.

6. A shale shaker as claimed in claim **1**, wherein said non-channeled flow tray further comprises a valve for directing said unchanneled flow of solids laden drilling fluid to one of said first screen deck and said pluralities of first and second flow ducts.

7. A shale shaker as claimed in claim **6**, wherein said non-channeled flow tray has at least one gate opening therein and said valve is a gate valve comprising a slidably movable gate tray that is adapted to be slidably moved between a closed position closing off said gate opening to an open position opening said gate opening.

8. A shale shaker as claimed in claim **7**, wherein a level of at least one of said pluralities of first and second duct openings is positioned below a level of said slidably movable gate tray.

9. A shale shaker as claimed in claim **1**, further comprising a scalping screen that is positioned above said non-channeled flow tray, said scalping screen being adapted to remove a portion of said solids from said solids laden drilling fluid, to direct said unchanneled flow of solids laden drilling fluid to said non-channeled flow tray and to direct said removed portion of said solids to a discharge end of said shale shaker.

10. A shale shaker as claimed in claim **9**, wherein said scalping screen is further adapted to direct said removed portion of said solids into one of a: skip;

and ditch.

11. A shale shaker as claimed in claim **1**, wherein said first screen deck has a screened fluid flow tray positioned thereunder, said screened fluid flow tray being adapted for collecting and guiding drilling fluid that is screened by said first screen deck.

12. A shale shaker as claimed in claim **11**, wherein said basket further comprises at least one discharge duct for directing said screened drilling fluid from said screened fluid flow tray to a sump arranged beneath said basket.

13. A shale shaker as claimed in claim **1**, wherein said second screen deck has a screened fluid flow tray positioned thereunder, said screened fluid flow tray being adapted for collecting and guiding drilling fluid that is screened by said second screen deck.

14. A shale shaker as claimed in claim **1**, wherein said basket further comprises a trough that is arranged under a solids discharge end of said first screen deck, said trough being adapted to receive solids discharged from said solids discharge end.

15. A shale shaker as claimed in claim **14**, further comprising a sump arranged below said basket, wherein said trough is adapted to feed solids into said sump.

16. A shale shaker as claimed in claim **15**, wherein the basket further comprises a flexible duct that is adapted to direct a flow of solids from said trough to said sump.

17. A shale shaker as claimed in claim **14**, said basket further comprising a jetting nozzle that is adapted to jet screened drilling fluid into said trough to facilitate a flow of solids therethrough.

18. A shale shaker as claimed in claim **1**, wherein said basket further comprises a trough and a diverter plate, wherein said trough is arranged under a solids discharge end of said first screen deck and said diverter plate is adapted to guide solids discharged from said solids discharge end into said trough.

19. A shale shaker as claimed in claim **1**, wherein said basket further comprises a trough and a diverter plate, wherein said trough is arranged under a solids discharge end of said first screen deck and said diverter plate is adapted to inhibit solids discharged from said solids discharge end from flowing into said trough.

20. A shale shaker as claimed in claim **19**, further comprising one of a skip and a ditch, wherein said diverter plate is adapted to guide solids into said one of said skip and said ditch.

21. A shale shaker as claimed in claim **1**, wherein said first screen deck comprises a left-hand first screen deck and a right-hand first screen deck.

22. A shale shaker as claimed in claim **21**, wherein said second screen deck comprises a left-hand second screen deck and a right-hand second screen deck.

23. The shale shaker of claim **22**, wherein at least two of said plurality of first flow ducts are adapted to feed said left-hand first screen deck, at least two of said plurality of first flow ducts are adapted to feed said right-hand first screen deck, at least two of said plurality of second flow ducts are adapted to feed said left-hand second screen deck, and at least two of said plurality of second flow ducts are adapted to feed said right-hand second screen deck.

24. A shale shaker as claimed in claim **1**, wherein said basket has a feed end and a solids discharge end, said first screen deck being arranged at an uphill angle relative to horizontal from said feed end of said basket to said solids discharge end.

25. A shale shaker as claimed in claim **1**, further comprising a first screen assembly in said first screen deck and a second screen assembly in said second screen deck.

26. A shale shaker as claimed in claim **25**, wherein said first screen assembly has first screening material thereon and said second screen assembly has second screening material thereon, wherein the mesh size of the first screening material is substantially the same as the mesh size of the second screening material.

27. A shale shaker as claimed in claim **25**, wherein said first screen assembly has first screening material thereon and said second screen assembly has second screening material thereon, wherein the mesh size of the second screening material is finer than the mesh size of the first screening material.

28. A shale shaker as claimed in claim **1**, further comprising a fixed base, said basket suspended from the base on at least one spring, said basket further comprising a vibrating apparatus for vibrating said basket and the first and second screen decks mounted therein.

29. A method for separating solids from solids laden drilling fluid, the method comprising:

directing an unchanneled flow of solids laden drilling fluid in a flow direction along a non-channeled flow tray, wherein said non-channeled flow tray is mounted in a basket of a shale shaker;

feeding said unchanneled flow of solids laden drilling fluid to a flow manifold of said shale shaker, said flow manifold comprising a plurality of first flow ducts and a plurality of second flow ducts interleaved with said first flow ducts;

receiving a first portion of said unchanneled flow with said plurality of first flow ducts, and channeling said first portion with said plurality of first flow ducts to a first screen deck mounted in said basket below said non-channeled flow tray; and

receiving a second portion of said unchanneled flow with said plurality of second flow ducts, and channeling said second portion with said plurality of second flow ducts to a second screen deck mounted in said basket below said first screen deck.

30. A shale shaker for separating solids from solids laden drilling fluid, the shale shaker comprising:

a basket;

a scalping screen mounted in said basket;

a non-channeled flow tray mounted in said basket and positioned below said scalping screen;

a first screen deck mounted in said basket and positioned below said non-channeled flow tray;

a second screen deck mounted in said basket and positioned below said first screen deck; and

a flow manifold comprising a plurality of first flow ducts and a plurality of second flow ducts interleaved with said first flow ducts, wherein said flow manifold is adapted to receive an unchanneled flow of solids laden drilling fluid from said non-channeled flow tray, said plurality of first flow ducts being adapted to receive a first portion of said unchanneled flow and channel said first portion to said first screen deck, and said plurality of second flow ducts being adapted to receive a second portion of said unchanneled flow and channel said second portion to said second screen deck.

31. A shale shaker as claimed in claim **30**, wherein said non-channeled flow tray has at least one gate opening therein and a gate valve comprising a slidably movable gate tray that is adapted to be slidably moved between a closed position closing off said gate opening to an open position opening said gate opening and allowing solids laden drilling fluid to flow therethrough.

32. A shale shaker as claimed in claim **31**, wherein said basket further comprises a screened fluid flow tray mounted therein and positioned below said first screen deck, said screened fluid flow tray having a selector opening therein and a selector gate valve that is adapted for selectively opening and closing said selector opening to selectively allow screened drilling fluid to flow therethrough and onto said second screen deck.

33. A method for separating solids laden drilling fluid with a shale shaker, the method comprising:

feeding a flow of solids laden drilling fluid to a scalping deck that is mounted in a basket of said shale shaker;

separating at least a first portion of solids material from said flow of solids laden drilling fluid by passing said at least said first portion of solids material over a scalping screen of said scalping deck to a discharge end of said scalping deck;

passing a flow of a first unseparated portion of said solids laden drilling fluid through said scalping screen to a first screen deck that is mounted in said basket and positioned below said scalping deck;

separating at least a second portion of solids material from said flow of said first unseparated portion of said solids laden drilling fluid by passing said at least said second portion of solids material over a first screen assembly of said first screen deck to a discharge end of said first screen deck; and

guiding a flow of said at least said second portion of solids material into a trough that is mounted in said basket and positioned adjacent to said discharge end of said first screen deck, wherein guiding said flow comprises guiding said flow with a diverter plate that is operatively coupled to said trough.

34. A method in accordance with claim **33**, further comprising flowing said at least said second portion of solids from said trough into a sump positioned under said basket.

35. A method in accordance with claim **34**, wherein flowing said at least said second portion of solids through the trough is facilitated by a jet of drilling fluid.

36. A method in accordance with claim **34**, further comprising passing a flow of a second unseparated portion of said solids laden drilling fluid through said first screen assembly to a second screen deck that is mounted in said basket and positioned below said first screen deck, and separating at least a further portion of solids material from said flow of said second unseparated portion of said solids laden drilling fluid by passing said at least said further portion of solids material over a second screen assembly of said second screen deck to a discharge end of said second screen deck.

37. A method in accordance with claim **36**, further comprising passing a flow of a further unseparated portion of said solids laden drilling fluid through said second screen assembly to said sump.

38. A shale shaker for separating solids from solids laden drilling fluid, the shale shaker comprising:

a basket;

a first screen deck mounted in said basket, wherein said first screen deck is adapted to receive a flow of said solids laden drilling fluid and separate said flow of said solids laden drilling fluid into a flow of a first solids portion and a flow of a first solids laden drilling fluid portion;

a second screen deck mounted in said basket below said first screen deck, wherein said second screen deck is adapted to receive at least part of said flow of said first solids laden drilling fluid portion and separate said at least said part of said flow of said first solids laden drilling fluid portion into a flow of a second solids portion and a flow of a second solids laden drilling fluid portion;

a sump positioned below said basket, wherein said sump is adapted to receive said flow of said first solids portion and said flow of said second solids laden drilling fluid portion;

a trough arranged in said basket at a solids discharge end of said first screen deck, wherein said trough is adapted to receive said flow of said first solids portion discharged from said first screen deck and direct said flow of said first solids portion to said sump for mixing with said flow of said second solids laden drilling fluid portion; and

a diverter plate that is adapted to selectively allow said flow of said first solids portion discharged from said first screen deck to flow into said trough.

39. A shale shaker as claimed in claim **38**, further comprising a flexible duct leading from said trough to said sump.

40. A shale shaker as claimed in claim **38**, further comprising a scalping deck mounted in said basket, wherein said first screen deck is adapted to receive said flow of said solids laden drilling fluid from said scalping deck.

41. A shale shaker as claimed in claim **38**, further comprising a scalping deck mounted in said basket above said first screen deck, wherein said first screen deck is adapted to receive said flow of said solids laden drilling fluid from said scalping deck.

42. A shale shaker as claimed in claim **38**, wherein each of said first and second screen decks are arranged in said basket at an uphill angle relative to horizontal from a respective feed end to a respective solids discharge end.

43. A method for separating solids from solids laden drilling fluid, the method comprising:

directing a flow of said solids laden drilling fluid to a first screen deck mounted in a basket of a shale shaker;

separating said flow of said solids laden drilling fluid with said first screen deck into a flow of a first solids portion and a flow of a first solids laden drilling fluid portion;

discharging said flow of said first solids portion from a discharge end of said first screen deck;

directing at least part of said flow of said first solids laden drilling fluid portion to a second screen deck mounted in said basket below said first screen deck;

separating said at least said part of said flow of said first solids laden drilling fluid with said second screen deck into a flow of a second solids portion and a flow of a second solids laden drilling fluid portion;

discharging said flow of said second solids portion from a discharge end of said second screen deck;

directing said flow of said second solids laden drilling fluid portion to a sump positioned below said second screen deck;

selectively directing said flow of said first solids portion discharged from said discharge end of said first screen deck to said sump; and

mixing said flow of said first solids portion with said flow of said second solids laden drilling fluid portion.

* * * * *